

## **Volume III, Chapter 3: Specific Source Descriptions**

### **Introduction**

The following specific sources and source categories are discussed in detail in this chapter.

#### **FUEL COMBUSTION AND ENERGY**

Coal Combustion

Fuel oil combustion: distillate (including #2 fuel oil, diesel fuel, kerosene, and jet fuel)

Fuel oil combustion: residual (including #4 and #6 fuel oil)

Gasoline combustion

Natural gas combustion

Petroleum refining

Wood combustion

#### **PRODUCTS AS A MERCURY SOURCE**

Cultural uses

Fluorescent lamps

Industrial and commercial sources not elsewhere listed

Iron and steel manufacturing and ferrous scrap processing

Mercury-containing products in general use

Non-ferrous metals, including aluminum and aluminum scrap processing

Painted surfaces

#### **HEALTH, EDUCATION, AND RESEARCH FACILITIES**

Crematoria

Dental office waste

Laboratories

Medical waste incineration

Medical waste, not incinerated

#### **WASTE AS A MERCURY SOURCE**

Dredged materials management

Hazardous waste incineration

Hazardous waste sites

Landfill gas

Landfill leachate

Municipal solid waste combustion

Municipal solid waste deposited in landfills

Sludge management: incineration, land application, and disposal

Soils, contaminated: thermal treatment

Wastewater

#### **NATURALLY OCCURRING EMISSIONS**

## APPENDIX A, EVALUATION OF CONTROL OPTIONS FOR THREE SOURCE CATEGORIES

## APPENDIX B, CALCULATION OF MERCURY RELEASES FROM PRODUCTS IN USE AND DURING THE WASTE DISPOSAL PROCESS (NOT INCLUDING FLUORESCENT TUBES)

## APPENDIX C, CALCULATION OF POTENTIAL MERCURY AIR EMISSIONS FROM THE LAND DISPOSAL OF DREDGED MATERIALS

Each source-specific discussion is a product of an iterative process carried out by the Sources Subcommittee. In this process, Subcommittee volunteers prepared the initial version of each write-up. A second Subcommittee member, not a representative of an industry associated with the source, then reviewed and revised the initial version. All available resources were used for information, including NJDEP authorized stack tests and specific sampling efforts. Subsequent reviews and revisions were carried out as necessary based on discussions at Subcommittee meetings and conference calls. References and details are in a spreadsheet available from the NJDEP Division of Science, Research, and Technology.<sup>1</sup>

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<sup>1</sup> Contact Michael Aucott, NJDEP, DSRT, PO Box 409, Trenton, NJ 08625-0409, 609-984-6070, [maucott@dep.state.nj.us](mailto:maucott@dep.state.nj.us).

## Coal Combustion

### Identification and Description of Source

As of December, 2000, there are 10 coal-fired electric generating units in New Jersey. Three are operated by an investor-owned utility (Conectiv), one by a municipal utility (City of Vineland), and three each by a wholesale generator (PSEG Power) and an independent power producer (PG&E Generating). Since Conectiv has committed to selling its units, it is expected that in early 2001, none of the 10 coal-fired electric generating units in New Jersey will be owned by investor-owned utilities. However, all 10 facilities are expected to continue to operate in New Jersey. Increased costs in natural gas and other fuel oils may in fact increase coal fired electricity generation in New Jersey.

### Quantity and Estimated Uncertainty

NJDEP stack tests performed from 1994 through 1997 indicate that these units collectively emit to the air about  $700 \pm 300$  lb. of mercury annually. However, recent nationwide data from the USEPA, based on reported plant fuel use and mercury tests at other plants made available pursuant to EPA's 1999 information request, estimate that New Jersey coal-burning utilities release 200 lbs. of mercury annually. EPA reportedly based its estimates on: measurements of the mercury content of coals sampled at approximately every 6<sup>th</sup> shipment; the actual consumption of coal at the plants; and the calculated mercury capture rates based on type of plant and control devices at each unit. Stack test data at a number of plants around the country were used to develop the estimates of the capture rates for certain types of plant and control device. The NJDEP stack test data are used as the basis for the emission estimate from this sector because the EPA emissions factors were not developed based on data from New Jersey plants.

Mercury emissions also occur from out-of-state combustion of coal associated with the generation of electricity used in New Jersey. The quantity of these emissions can be estimated from energy use data. Most electricity imported to New Jersey flows through the PJM Interconnection power control area (PJM). The generation resource mix of the PJM in 1998 was 47% coal.<sup>2</sup> In 1999, in-state coal combustion supplied approximately 70 quadrillion Btus of energy to the generation of electricity used in NJ, whereas energy consumed in the generation of imported electricity totaled approximately 300 quadrillion Btus.<sup>3</sup> Assuming that 47% of the imported electricity was generated with coal combustion, approximately 150 quadrillion Btus were released by out-of-state coal combustion in the generation of electricity used in New Jersey. With the assumption that associated mercury emissions are proportional, perhaps 1500 pounds of mercury are released from out-of-state coal combustion to generate electricity imported to New Jersey. If these emissions are added to the estimated  $700 \pm 300$  lbs./yr. noted above, the total

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<sup>2</sup> USEPA, 2001, Emission and Generation Resource Integrated Database, Version 2.0, USEPA Office of Atmospheric Programs, Washington, DC, September, 2001.

<sup>3</sup> US Department of Energy, Energy Information Administration (USDOE/EIA), 2001, NJ State Energy Data Report, data file, downloaded from <http://www.eia.doe.gov/pub/state.data/data>, 10/29/99; new data rec'd 5/10/01 w. e-mail to M. Aucott, NJDEP, from Julia Hutchins, DOE/EIA.

mercury emissions from coal combustion associated with New Jersey electricity consumption is approximately  $2200 \pm 1000$  pounds per year.

### **Sectors Affected**

In terms of electricity generation and use, supply side refers to the production of electricity and demand side refers to the use of electricity. On the supply side, the sectors affected would be the electric power producers. On the demand side, the sectors affected are the commercial, residential and industrial consumers of electricity.

### **Receiving Media**

The initial receiving medium is the air. As noted below, emissions are primarily elemental and oxidized gaseous species. Elemental mercury tends to circulate around the world, and ultimately is deposited on the land and water. Oxidized mercury tends to be deposited (in rainfall, snowfall, or as dry deposition) within a relatively short distance of the source.

### **Chemical Species**

This mercury is primarily in the vapor phase, either as the free element ( $\text{Hg}^0$ ) or in an oxidized form ( $\text{Hg}^{++}$ ).

### **Reduction Options and Associated Costs and Impediments**

Source reduction options include generation efficiency improvements, coal cleaning, fuel switching, and substitution with renewable energy. On the demand side, source reduction options include increased energy efficiency of devices that use electricity<sup>4</sup> and substitution of non-electricity-powered devices. Emission control options include carbon (or other sorbent) injection and wet scrubbing (FGD).

### **Source Reduction Options**

#### ***Supply Side***

Coal cleaning is a process of purification performed on raw coal to obtain a high-energy, low-sulfur, low-moisture and minimum-ash final product. Various cleaning methods are used individually or in combination with one another, depending on the characteristics of the coal and the degree of cleaning needed to meet the specifications. These methods include crushing, size sorting, density sorting (flat/sink cleaning) and froth flotation. Optimization of the coal cleaning process relies on the supplier's criteria for meeting the overall specifications. The supplier is concerned with maximizing his yield, expressed as a percentage of raw coal mined, with minimal treatment.

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<sup>4</sup> For example, replacing single speed electric motors with variable speed motors to match the load, replacing inefficient incandescent lighting with high efficiency fluorescent lights, and replacing inefficient appliances with more efficient models.

Coal cleaning is already performed on the coal burned in 8 of the 10 New Jersey power plants. Deep cleaning, which requires a somewhat more sophisticated approach than conventional cleaning, and is thus more expensive, may be able to reduce the mercury content on a pounds per Btu basis. This technology has not been fully developed, and its efficacy is highly dependent on the original coal. Some coals experience an increase in mercury content (on a pounds per Btu basis) as a result of deep cleaning. It is estimated that additional cleaning of Central Appalachian coals to 2% ash content would add \$6/ton to their cost, increasing coal cost by about a third. Such deep cleaning has not yet been deployed commercially.

Any effort that will reduce energy usage including increased production efficiency will have the collateral effect of lessening the environmental impact of this category. Switching to other types of fuel that have a lower mercury content would also lead to reductions of emissions from the coal combustion source.

Another supply side option is the replacement of fossil fuel electricity generation with a renewable energy source that has low or no mercury emissions. Class I renewable energy sources are defined in the Electric Discount and Energy Competition Act (Act) as photovoltaic, wind, wave, or tidal power, solar thermal electric, fuel cells, or geothermal. Class II renewable energy sources are municipal solid waste incinerators that generate electricity and hydroelectric electricity generation. Nuclear energy is not defined as a renewable source. As required in the Act, all energy suppliers selling electricity in New Jersey must comply with a Renewable Portfolio Standard (RPS). This means that a portion of the electricity in each suppliers' overall electricity portfolio must be generated from Class I or II renewable energy. The initial renewable energy percentage requirement for Class I is 0.5 %. The percentage increases to 6.5% in 2012 of which 2.5% is to be from Class I or Class II renewables and 4% is from Class I. Currently, New Jersey uses 68 million megawatt hours (million Mwh) of electricity yearly. Per the requirements of the Act, in 2012 approximately 2.7 million Mwh must be supplied by Class I renewables and 1.7 million Mwh must be supplied by Class I or II renewables.

### ***Demand Side***

A cost-effective tool for reducing overall emissions is demand side energy efficiency improvements. Increasing the efficiency of devices that use electricity could reduce the amount of coal burned, thereby reducing the amount of mercury emissions. In addition, demand side energy efficiency would also reduce the emissions of CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, particulates and other trace metals.

The amount of reduction in mercury emissions achieved through demand side energy efficiency will vary depending on the fuel used to generate the electricity. U. S. average electricity generation is 52% coal, 18% nuclear, 14% gas, 13% renewable (82% hydro, 13% biomass, 5% other renewables), and 3% oil (1997).<sup>5</sup> In New Jersey the fuel used for electricity generation are

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<sup>5</sup> USDOE, 1997, *Energy Information Agency Electric Power Annual 1997, STAPPA/ALAPCO Reducing Greenhouse Gases - A Menu of Harmonizing Options Final Report* October 1997

58% nuclear, 28% coal, 12% gas and 2% oil (1997).<sup>6</sup> Demand side energy efficiency improvements that displace electricity generated through nuclear power or non-biomass renewable energy sources will not provide mercury emission reductions since these sources do not emit mercury. Demand side energy efficiency improvements that displace natural gas and fuel oils will result in very small mercury emission reductions. Demand side energy efficiency improvements will result in substantial mercury emissions reductions from utilities that rely heavily on coal.

This issue is compounded by the fact that New Jersey does not generate in-state, all the electricity it consumes. Of the 68 million MWh of electricity used in New Jersey each year, 21% is imported into the state through the PJM pool from out-of-state sources (1998)<sup>7</sup>. With restructuring of the energy markets in New Jersey as a result of the New Jersey Electric Discount and Energy Competition Act, to provide for open market competition, it is expected that the importation of electricity will increase.<sup>8</sup> There is no current way to ensure that a kilowatt reduction resulting from demand side energy efficiency will have a corresponding reduction in mercury emissions.

However, there are ways to increase the effectiveness of energy efficiency strategies to reduce mercury emissions. They include a two-prong approach. One is implementing an outreach and education program with the objective of promoting an understanding by electricity users of the overall environmental impacts of the electricity they use, including mercury emissions. This program would focus on the overall environmental impacts of the various sources and fuels used to generate electricity including fossil fuel, nuclear and renewables. This would encourage users to consider and select electricity from renewable sources. The other is to develop a national energy policy with a program that interconnects the various goals and objectives of the individual state programs for energy efficiency and renewable energy programs.

If electricity users understood the overall environmental impacts of the various fuels that made up their energy supply including coal, nuclear, natural gas, oil, hydro, biomass wind, and photovoltaic; and the emissions levels of these fuel mixes (including  $CO_2$ ,  $NO_x$ ,  $SO_2$  and Hg), they could then make the informed choice to use electricity generated by a low or no mercury fuel source. This energy choice would be similar to the choice consumers now make to buy low fat or no fat food product based on the nutritional fact labels on food products.

As a result of the recently enacted Electric Discount and Energy Competition Act N.J.S.A. 48:3-49 et seq. (P.L. 1999 c. 23), consumers of electricity have a choice of the electric supplier that generates their energy. In order to ensure that the choice of the electric supplier is not made solely on the cost of that service, the Act requires that the electric suppliers or basic generation service providers disclose the environmental characteristics of the energy purchased by the customer including the following:

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<sup>6</sup> USEPA E-GRID electric database for New Jersey 1998

<sup>7</sup> PJM -GRID electric database for New Jersey 1998

<sup>8</sup> USDOE - Energy Information Agency Electric Power Annual 1997

1. The fuel mix including fossil, nuclear and renewable sources;
2. The emissions in pounds per MWh for CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub>; and
3. The electricity supplier's support of energy efficiency as reflected by the retirement of discrete emissions reduction credits.

This label of the environmental characteristics of the energy purchased does not currently include mercury. The Act allows the New Jersey Board of Public Utilities (BPU) to add other pollutants to the disclosure rule, if determined to pose an environmental or health hazard.

The disclosure rules are in effect as interim standards until March 2002 unless final standards are adopted by the BPU prior to that time. The BPU, in consultation with the NJDEP, may amend or readopt the current interim regulations in accordance with the Administrative Procedures Act at NJSA 52:14B-1 et seq. The department as part of its environmental consultative role to the BPU, can make a finding to the BPU that mercury poses an environmental and health hazard. Further, as part of the environmental advice, the department can recommend to the BPU to include mercury as a new pollutant on the disclosure label, within its rule-making process.

### **Control Options**

Particulate control systems are not effective for pollutants that are in the vapor phase. They do not efficiently capture gaseous pollutants that are carried with the combustion fine particles. However, sorbents can be used to adsorb the vapor-phase metals onto solid particles (the sorbent) large enough to be collected in the particulate control system.

The primary sorbent used for air toxics control is activated carbon. Activated carbon is injected in powder form into the flue gas upstream of the particulate control device. After injection into the flue gas and adsorption of mercury and other contaminants, the activated carbon is captured in the particulate control device. Activated carbon has been used in municipal waste combustors (MWC) and medical waste incinerators (MWI) with success. However, the concentration of the contaminants in the flue gas of those facilities is significantly higher than in the flue gas streams of coal-fired boilers. The mercury concentration in uncontrolled flue gas of many coal-fired boilers is in the same range as the exit concentration in controlled MWCs and MWIs.

Laboratory-scale and slipstream tests of activated carbon have been conducted on coal-fired boiler flue gas. These tests, having been conducted with various types of coal, greatly differing flue gas conditions and compositions, varying amounts and speciation of mercury, and differing rates of activated carbon injection, show great promise. Mercury removal efficiencies have varied from about 30% to about 90%. Generally speaking, mercury removal is enhanced by higher injection rates of activated carbon and lower flue gas temperatures.

According to EPA, efficient distribution of the activated carbon in the flue gas is also important. The amount of sorbent needed to achieve a specific level of mercury removal will vary depending on the fuel being burned, the amount of chloride present in the fuel and the type of

particulate matter control device. At a given sorbent feed rate, a fabric filter provides more mercury control than an electrostatic precipitator (ESP) because of the additional adsorption that occurs on the bags of the fabric filter and due to the increased gas contact time. As a result, an ESP-equipped facility may require a higher carbon feed rate to achieve the same level of control as a fabric-filter-equipped facility.

Activated carbon feed rates may range from 1,000 to 100,000 pounds per pound of mercury removed and may produce 90% removal. Depending on the specific conditions assumed, EPA has quoted in its Mercury Study Report to Congress<sup>9</sup> cost estimates from \$5,000 to \$70,000 per pound of mercury removed. Other costs may be added to the process, such as disposal costs, etc. As the cost of sorbents decline, so do the costs per pound of mercury captured. However, the cost of the sorbent must be weighed against the amount of sorbent needed. Some lower-per-pound cost sorbents may require higher sorbent use, thereby eliminating some of the saving.

Generally, the lower the fraction of the mercury which is present in the flue gas in the elemental form, the higher the total mercury removal efficiency. This is because mercury compounds ( $\text{Hg}^{+II}$ ) are more easily removed than elemental mercury ( $\text{Hg}^0$ ). The presence of chloride in the coal tends to increase the fraction of  $\text{Hg}^{+II}$  in the flue gas. The presence of  $\text{SO}_2$  tends to increase the fraction of  $\text{Hg}^0$ , thereby reducing the ability of activated carbon to capture mercury. There is some indication that total mercury removal increases with the increase of unburned carbon (loss on ignition) in the fly ash.

The injection of activated carbon into a utility flue gas stream could have a significant impact on the quantity and quality of particulate matter requiring disposal. EPA has estimated that a 100-MW coal-fired boiler with an ESP could potentially inject about 490 tons of activated carbon per year, which would be about 2.5% of the total ash (20,000 tons/yr).<sup>10</sup> It is believed that ash collected during carbon injection could be landfilled if not salable. While further tests of coal ash with carbon would be useful, municipal solid waste ash tests have demonstrated that the mercury collected on the activated carbon is stable at temperatures typical of landfills and is not re-emitted to the atmosphere.<sup>11,12,13</sup>

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<sup>9</sup> USEPA, 1997, *Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs*, EPA-452/R-97-010, p. ES-4

<sup>10</sup> USEPA, 1997, *Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs*, EPA-452/R-97-010, p. 2-28.

<sup>11</sup> Electric Power Research Institute (EPRI), 1999, *The Stability of Mercury Captured on Sorbent Surfaces*, EPRI, Palo Alto, CA, TE-113926, October 1999.

<sup>12</sup> U.S. Department of Energy, 1999, *Mercury Stability in the Environment*, Final Topical Report, DOE Cooperative Agreement No. DE-FC26-98FT40320, Task 1.2, July 1999 (available from the Federal Energy Technology Center)

<sup>13</sup> Brown, Thomas D., Smith, Dennis N., Hargis, Richard A. Jr., and O'Dowd, William J., 1999, U.S. Department of Energy, Federal Energy Technology Center, "Mercury Measurement and Its Control: What We Know, Have Learned, and Need to Further Investigate," *Journal of the Air & Waste Management Association*, June 1999.



Chemically impregnated activated carbon can be used to enhance mercury removal over the more traditional activated carbon. With chemically impregnated activated carbon, the mercury reacts with the chemical that is bound to the carbon, and the compound, as before, is removed by the particulate control device. Chemically impregnated carbons require smaller rates of carbon injection than does activated carbon for equivalent mercury removals. The required carbon-to-mercury mass ratio may be reduced by a factor of from 3 to 10 with the chemically impregnated carbons. However, the cost per mass unit of impregnated activated carbon may be significantly greater than that of unmodified activated carbon.

Impregnated activated carbons have been tested on European MWCs and MWIs. Some of the impregnated activated carbons that are available commercially were developed for other applications and cannot tolerate the high temperatures encountered in utility flue gas streams. Typical impregnants for activated carbon are chloride, sulfur, iodide, and silver. Another commercially available material, Sorbalit<sup>TM</sup>, is a mixture of lime with additives and 3-5% activated carbon.

A number of more novel sorbents are being investigated at the laboratory level. These include activated carbon impregnated with recycled silver from waste photographic material and sulfur-impregnated activated carbon derived from waste tires. At the other (high) end of the cost scale, gold dispersed on either activated carbon or alumina is being evaluated.

In order to minimize the total amount of toxic waste in the process, non-toxic food additives are being investigated, with some success, as candidate sorbents for mercury removal from utility flue gas streams.

Zeolites comprise another category of non-toxic sorbent. There are naturally occurring mineral zeolites, in addition to commercially available synthetic zeolites. Fixed blends of these substances have been proposed for variety of mercury control applications, but none have been developed specifically for control of mercury in coal flue gas. Zeolites have not been proven effective sorbents for mercury control. However, it may be possible to manufacture specifically tailored zeolites for this purpose. Control cost will depend on effectiveness of tailored zeolite in removing mercury. A highly effective zeolite has the potential to require much less sorbent than various activated carbons, and would not affect ash quality.

PSE&G has hosted pilot scale demonstrations of mercury removal technologies at its Hudson and Mercer plants with good success. The technology piloted at Hudson is the EPRI TOXECON procedure, in which activated carbon or a combination of activated carbon and an alkaline material, e.g., lime, is sprayed into the flue gas upstream of a small pulse-jet fabric filter (COHPAC). The pilot results indicated that very high (up to 90%) mercury removal could be achieved under certain conditions. At Mercer, Environmental Elements Corporation produced reasonably good mercury removals with a circulating fluidized bed ash utilizing injected activated carbon.

Water injection into the flue gas at the entrance to a cold-side electrostatic precipitator might cause sufficient cooling of the stream to allow more mercury to be collected with or without sorbent injection.

At Logan (PG&E Generating), where a spray dryer is used to lower the temperature of the flue gas, the temperature of the flue gas entering the baghouse is near the condensation point for mercury. This lower temperature apparently causes a significant portion of the mercury entering the particulate control device to be particulate-bound, and this mercury is therefore captured by the particulate control system. Also, the fly ash removed in the baghouse, some of which adheres to the bag surface, contains significant unburned carbon that may act as a sorbent for mercury much the way activated carbon does. There is also some indication that the catalyst employed in the Selective Catalytic Reduction system for NO<sub>x</sub> removal may cause Hg<sup>0</sup> to transform to Hg<sup>+II</sup>, and thereby improve mercury removal.

### **Research, Development, and Monitoring Options**

Monitoring instrumentation is being developed to provide real time stack gas analysis for mercury. Tests conducted by EPA and DOE indicate that these instruments are not yet ready for commercial installation in the field.<sup>14</sup> The instruments tested were capable of measuring mercury concentrations with a precision of  $\pm 20\%$ .

PSE&G has sponsored a number of pilot-scale and full-scale demonstrations of continuous emissions monitoring (CEM) for mercury at its Mercer facility. One of the full-scale CEM technologies that was presented to the Mercury Task Force and evaluated by NJDEP was the Edison Electric Institute (EEI) technology. The EEI CEM technology is based on plasma emission spectroscopy and demonstrated good sensitivity in the 0.1 : g/m<sup>3</sup> range with cost, as represented by EEI, comparable to periodic stack testing for mercury.

Monitoring efforts at present consist of compliance with the EPA Information Collection Request, which required in 1999 the determination of the mercury and chlorine content of at least three coal shipments per month to each coal-fired generating station in the country. The results are expected to provide a reasonable first approximation of the actual amount of mercury going into the coal-fired utility boilers in the United States. Also, representative samples of coal-fired units across the country were selected by EPA to conduct stack sampling and analysis to determine speciation and emission rate of mercury. Those results are expected to provide a reasonable first approximation of the actual amount of mercury being emitted from coal-fired utility boilers in the United States, as well as identify mercury removal effectiveness of existing power plant equipment and control apparatus.

### **Outreach and educational options**

#### **Supply Side**

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<sup>14</sup> USEPA, 2000, Workshop on Source Emission and Ambient Air Monitoring of Mercury, September 13-14, 1999, Bloomington, MN, EPA /625/R-00/002, June 2000, p. 72-74.

Starting for reporting year 2000, the USEPA lowered the reporting threshold for mercury for the Toxic Release Inventory (TRI) to 10 pounds per year. Also, electric generating plants are required to report releases for TRI starting with reporting year 1998. Consequently, annual data for mercury emissions from electric power production, as well as other emitters whose emissions were not reported because these emitters were previously below the threshold, will be available in 2001. The mercury data for power production as well as other reporting sources should be evaluated and presented to the public annually, with 5-year trends provided in the future.

## **Demand Side**

The information on electricity generation sources and emission rates for CO<sub>2</sub>, SO<sub>2</sub> and NO<sub>x</sub> is currently available on the disclosure labels from all retail energy suppliers selling to consumers in New Jersey. For new suppliers doing business in New Jersey, this information was based on a default label for the year 2000, but is based on actual emissions and generation sources in 2001. For existing suppliers, this information was based on historical values. The department should, in consultation with the BPU and other state agencies, develop and implement an effective outreach and education program to promote the purchase of 'green power' by the residential, commercial and industrial sectors. 'Green power' is defined as electricity generated from a set percentage of Class I or Class II renewable energies or that is generated with overall environmental impacts below an established environmental baseline.

This demand side outreach and education program to the public to promote the purchase of green power should include a component on low and no mercury electricity sources. The outreach and education program should be developed in consultation with the utilities and energy services contractors (ESCOs), and incorporated with energy efficiency programs for the residential, commercial, industrial and institutional/government sectors promoting strategies for energy conservation and innovative technology.

In January 2000 the NJDEP released its Sustainability - Greenhouse Gas Action Plan. The NJDEP Greenhouse Gas (GHG) Action Plan established a goal to reduce GHG emissions in NJ by 3.5% below the 1990 level by 2005. This will require a 20.5 million metric ton of CO<sub>2</sub> equivalent reduction in projected CO<sub>2</sub> levels across all sectors. The GHG Action Plan evaluated 'no-regrets' strategies that could reasonably be advanced to reach the Action Plan's short-term goal. A 'no-regrets' strategy is defined as a specific measure that is currently commercially available with a simple payback period less than 4 years. The GHG Action Plan strategies include increased use of energy conservation, innovative technology, pollution prevention, recycling, and open space management. It is anticipated that New Jersey and the six other states participating in the Technology Acceptance and Reciprocity Partnership (TARP) sponsored by ECOS, will begin an initiative shortly to develop common protocols to combat climate change, expanding and coordinating the New Jersey initiated effort.

Many of these same strategies should also reduce the emissions of mercury. GHG emission reduction specific measures within each strategy and sector are listed in Appendix A. A component of the GHG Action Plan is the development and implementation of an effective outreach and education program to reduce GHG emission across all sectors utilizing the GHG

reduction strategies. An effective mercury reduction strategy would link the mercury energy efficiency and renewable energy outreach and education strategies to the GHG outreach and educational strategies.

As a result of the recently enacted Electric Discount and Energy Competition Act NJSA 48:3-49 et seq. (P.L. 1999 c. 23) there is established a societal benefits charge on the use of electricity in New Jersey. This charge, paid for by the New Jersey users of electricity, helps to fund several programs in New Jersey which have an overall societal benefit. One is subsidizing the energy purchase by consumers with low incomes. Another is the clean up of existing manufactured gas plant contaminated sites across New Jersey. Another is the subsidizing of programs that advance the market transformation in the use of energy efficiency and Class I renewable energy programs that have environmental benefits over and above the current demand side management programs and Class I renewable energy technologies. The energy efficiency and renewable energy fund of the societal benefits charge program will aid in the buy down of the higher initial capital cost of energy efficiency and renewable energies. This fund will greatly aid in meeting the NJDEP GHG emission reduction goal and other air emissions, including reducing mercury emission from energy use. The outreach and education program for mercury reductions should be considered for the societal benefits charge program for energy efficiency and renewable energy funding currently under development by the BPU in consultation with the NJDEP.

It is clear that New Jersey cannot achieve the goals of energy efficiency and renewable energy market transformation to reduce GHG or mercury emissions alone. Twenty-four (24) states have implemented energy restructuring programs. Of these programs, twelve (12) states have system or societal benefits charge programs for energy efficiency and renewable energy funding, some states have disclosure or labeling provisions and some states have Renewable Portfolio Standards. While reducing energy use and reducing mercury emissions are not proportional, reducing energy use will, in most cases, reduce mercury emissions.

The national state utility regulators, the national state environmental regulators, and the national state energy regulators should be encouraged to develop reciprocal interstate programs to establish nationally consistent energy efficiency and renewable energy goals to reduce mercury and CO<sub>2</sub>, as well as SO<sub>2</sub> and NO<sub>x</sub>. Linking separate state programs together begins to insure that a kilowatt reduction resulting from energy efficiency could have a corresponding reduction in mercury emissions.

### **Recommendations**

The Task Force encourages the development of mercury emission source reduction options and control technologies for coal-fired plants, and encourages the Department of Environmental Protection to work to obtain federal and interstate support to demonstrate such technologies and source reduction options at New Jersey facilities. Once control technologies have been demonstrated, the task force recommends that appropriate emission limits be established for coal-fired plants.

The Task Force supports a comprehensive National Energy Policy, and recommends that New Jersey legislators and policy makers spearhead an effort to embody principles and practices as delineated in this section.

## Specific Recommendations

1. The Department should promote energy efficiency with measures consistent with the NJDEP Greenhouse Gas Sustainability Action Plan. This promotion should include implementation of the outreach and education component of the New Jersey Sustainability GHG Action Plan and should expand this program to include the potential mercury emission reductions from the GHG emission reduction strategies.
2. The Department should promote the increased use of electric power from certified green sources including renewable sources and sources with low or zero mercury emissions. The GHG strategies of energy conservation and innovative technologies that promote demand side energy efficiency and supply side renewable energy should be linked to mercury emission reduction outreach and education programs.
3. New Jersey should require environmental information disclosure of mercury emissions per kilowatt-hour from all providers selling electricity in New Jersey consistent with The New Jersey Electric Discount and Energy Competition Act (EDECA) of 1999 (N.J.S.A. 48: 38). The Department, as part of its environmental consultative role to the BPU, should make a finding to the BPU that mercury poses an environmental and health hazard. Further, as part of the environmental advice, the Department should recommend to the BPU to include mercury as a new pollutant on the disclosure label, within its rule-making process when adequate data is available.
4. New Jersey should urge the US Environmental Protection Agency (EPA) to rapidly develop and implement stringent limits on mercury emissions from coal combustion. These standards should include output-based performance limits (mg/MW-hr), which are applied to individual coal-fired power plants, in addition to national caps (tons/year), which are applied to the electric generation source category as a whole. A discussion of potential standards is included as Appendix A, Evaluation of Control Options for Three Source Categories.
5. New Jersey should adopt State standards for coal combustion, if by December 2003 EPA does not proceed to promulgate and implement effective mercury limits on coal combustion.
6. Mercury in coal and mercury emission data generated by the EPA Information Collection Request and Toxics Release Inventory Data should be evaluated. Data should be converted to units of mass of mercury emitted per amount of energy production (i.e., mg/MW hr) for each power plant.
7. Mercury in coal and mercury emission data from coal-fired boilers should continue to be collected by the USEPA on a periodic basis. The mercury data reported pursuant to the TRI requirements for power production as well as other sources should be reviewed as well.

8. Full-scale demonstration projects should be implemented in the 2001 to 2003 timeframe, and experience with these projects should be considered in the establishment of standards.

9. Final compliance should be required in the 2007 to 2010 timeframe to enable coordination with other air pollution control measures also being required.

10. Measures should be established to ensure that the handling, storage, disposal and use of mercury containing ash and other by-products from mercury emission reduction technologies will not allow mercury reentry into the environment.

11. Consistent with the requirements of NJSA 48:3-49<sup>15</sup>, mercury portfolio standards should be established to encourage the use and development of electric generating sources with little or no mercury emissions. Such standards should be expressed in terms of mass of mercury emissions per MW hr of electricity supplied and should apply to the total amount of electricity sold by each retail supplier of electricity to all of its New Jersey customers.

12. New Jersey should work with interstate agencies to assist in the development of federal multi-pollutant legislation that limits mercury emissions. Mercury emissions should be reduced in conjunction with on-going measures to reduce other air pollutants. The State should initiate and foster a partnership between the PJM states to establish a regional mercury emissions portfolio standard. In addition, New Jersey should initiate and foster a partnership between the states, through its leadership role in national energy and environmental organizations including NARUC, NASEO, ECOS, STAPPA and OTC to evaluate the establishment of a national mercury emissions portfolio. This recommendation, to be effective, will require additional measures to ensure that the flow of electricity from low or non mercury-emitting generating sources is correctly attributed to these sources. A system needs to be implemented that adequately monitors the sources of the low or non mercury-emitting electricity, tracking it appropriately to the consumer of that electricity to ensure no double counting and in essence verifies the disclosure label.

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<sup>15</sup> The New Jersey Electric Discount and Energy Competition Act (EDECA) of 1999 (N.J.S.A. 48: 38 (c)(1), is clear that an emissions portfolio standard (EPS) for any pollutant can be implemented only if: Either two other states in the PJM grid, in addition to New Jersey, comprising 40% load in the PJM region, implement an EPS; or, upon a finding that the standard is necessary as part of a plan to enable the State to meet federal CAA or State ambient air quality standards. This finding requires notice and public comment. Currently, (12/2000) no other state in the PJM grid is pursuing an EPS for any pollutant. If New Jersey pursues the second option, the NJDEP will need to develop an air quality plan that includes the mercury portfolio standard recommendation, and hold public hearings before endorsing this strategy. A public case has to be made that shows this course of action is necessary to meet environmental and health goals, and that the fiscal and other impacts are reasonable.

13. The Department, in consultation with the BPU and other state agencies, should develop and implement an effective outreach and education program to promote the purchase of green power. This program should include a component on low- and zero-mercury electricity sources. The Task Force recommends that the NJDEP recommend to the BPU that this program should also be considered for the societal benefits charge program for energy efficiency and renewable energy funding currently under development by the BPU in consultation with the Department.



## **Fuel Oil Combustion: Distillate (Including #2 Fuel Oil, Diesel Fuel, Kerosene, and Jet Fuel)**

### **Identification and Description of Source**

Distillate fuels include jet fuels, diesel fuels, heating oil, and kerosene. In New Jersey, the consumption of heating oils ranks second only to gasoline in refinery product volume.<sup>16</sup> All distillate fuels are blends of the products and byproducts produced in petroleum refinery operating units. These blends are made to a performance specification based on their end use and not on a percentage of various hydrocarbon molecules present. A key specification on all petroleum products is its boiling range. Jet fuels have a boiling range of between 350°F and 550° F for commercial jets and 150°F and 550°F for military jets. Automotive and truck diesel fuels will have a boiling range between 350° F and 650° F. Railroad diesel fuels are the largest single market for diesel fuels and have a slightly higher boiling range than automotive diesel, which is 700° F. Heating oil and kerosene have a boiling range similar to automotive diesel.

Mercury is thought to exist as a contaminant in all distillate fuels. It is assumed that all mercury present in distillate fuels will be released into the atmosphere during the combustion process.

### **Quantity and Estimated Uncertainty**

No testing has been performed to quantify the total emissions from this source in the state of New Jersey. Mass balance calculations have been used to estimate the quantity released from this source. According to the U.S. Department of Energy, 36,317,000 barrels of distillate oil, which is approximately  $1.07 \times 10^{10}$  pounds and 211.5 trillion Btu, were consumed in New Jersey in 1997, the most recent year for which figures are available. The USDOE also reported that 38,738,000 barrels of jet fuel and 1,701,000 barrels of kerosene were consumed in the state in the same year.<sup>17</sup> The jet fuel combustion quantity, however, represents total jet fuel sold in the state, not which is consumed or produced in the state. Much of this jet fuel would be combusted by aircraft in flight throughout the globe.

The USEPA has used a factor of 7.2 pounds mercury emission per  $10^{12}$  Btu of distillate oil combusted.<sup>18</sup> Based on this emission factor, which translates to nearly 140 ppb,<sup>19</sup> and the quantity of distillate consumed in New Jersey as noted above, about 1500 pounds of mercury would be released by the combustion of distillate in New Jersey. This figure does not include the combustion of jet fuel. In the same report referenced above, the USEPA used an emission factor of 6.8 lbs. per  $10^{12}$  Btu for residual oil, and calculated, based on different fuel consumption figures, that the total combustion of residual and distillate oil in New Jersey released approximately 0.5 tons of mercury per year.

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<sup>16</sup> Morris, Robert, Coastal Corporation, personal communication, 2/16/00.

<sup>17</sup> USDOE, 1997, State Energy Data Report for New Jersey, U.S. Department of Energy, Energy Information Administration, downloaded from <http://www.eia.doe.gov/1pub/state.data/data>, December, 1999.

<sup>18</sup> USEPA, 1997, Mercury Study Report to Congress, Volume II; An Inventory of Anthropogenic Mercury Emissions in the United States, EPA-452/R-97-004, December, 1997.

<sup>19</sup>  $10^{12}$  Btu of distillate equates to about  $5 \times 10^7$  pounds.  $7.2/5 \times 10^7$  equates to approximately 140 ppb.

Based on recent data assembled by the New Jersey Mercury Task Force, the EPA estimates noted above are unrealistically high. As with other analyses of mercury content of fuels, values reported in the literature based on studies that pre-date the use of ultra-clean laboratory techniques are considered suspect. Ultra-clean techniques, essential for accurate analyses of media containing low levels of mercury, did not become widely used until around 1990; some analytical laboratories still do not use these techniques. Recent analyses of the mercury content of distillate fuels, including diesel oils and kerosene (similar to jet fuel), have shown consistently low values, in the range of 1 ppb.<sup>20,21</sup>

The mean of values reported in the recent studies was determined to be 0.5 ppb. Multiplying this by the estimated consumption of distillate (not including jet fuel) in New Jersey yields an estimated emission from this source of approximately 5 pounds per year. The inclusion of jet fuel, assuming it has a similar concentration adds another approximately 5 pounds to the total, even if it is assumed that all jet fuel sold in New Jersey is consumed in New Jersey.<sup>22</sup> The overall estimate from combustion of distillate fuel is in the range of 10 pounds or less. Because of the limited data available, there is considerable uncertainty, perhaps of the order of 75% or more, in this value. The discrepancy of this relatively low quantity with the much higher EPA estimates noted above should be resolved definitively with additional data.

### **Sectors Affected**

Diesel fuel is used primarily in heavy vehicles and emissions would be considered from mobile sources, both on- and off-road, throughout the State. Distillate oil is used for heating, electric power generation and steam production. Aircraft and airports use jet fuel. All public and private sectors are therefore affected by this source category.

### **Receiving Media**

Since this is an uncontrolled combustion process as far as mercury is concerned, the primary receiving medium is air.

### **Chemical Species**

The species emitted have not been confirmed through rigorous analysis or testing. Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species such as  $\text{HgCl}_2$ , and species bound to particulates are present. Fossil fuel combustion conditions create a milieu rich with methyl radicals<sup>23</sup> and from an energetic perspective, free radical reaction to produce  $\text{RHgX}$  is feasible.<sup>24</sup>

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<sup>20</sup>. Gilkeson, John, 1999, Mercury in Petroleum Refining: Crude Oil and Refined Products, Final Report to Legislative Commission on Minnesota Resources, DRAFT, Minnesota Office of Environmental Assistance, August 20, 1999

<sup>21</sup>. Liang, L., M. Horvat, and P. Danilchik, 1996, A novel analytical method for determination of picogram levels of total mercury in gasoline and other petroleum based products, *Science of the Total Environment*, 187, 57-64.

<sup>22</sup>. The reported mercury concentration for kerosene, considered similar to jet fuel, is 0.04 ppb in the Liang, et al. reference noted above.

<sup>23</sup>. Glassman, I., 1996, Chapter 3, pp. 90-94, The Oxidation of Methane, in *Combustion*, 3<sup>rd</sup> Edition, Academic Press, San Diego.

<sup>24</sup>. DeNoble, James P., 1999, Critical Review: *Atmospheric Methylmercury: Sources, Sinks, and Inferences for its De Novo Generation*, DRAFT Masters Thesis, Rutgers University, October, 1999.

## **Reduction Options and Associated Costs and Impediments**

Any effort that will reduce energy usage will have the collateral effect of lessening the impact of this category. No specific reduction options are proposed, however, because of the relatively low mercury concentration of this source.

Because of required product changes in the future, refinery processes will evolve. Evolution of oil refining processes may indicate ways to separate mercury from fuel products and further concentrate mercury in byproducts, which might be treated for mercury removal or disposed in ways that would not release mercury to air or water. The likelihood that mercury accumulates in the heavier liquid or solid products or byproducts (see discussion on oil refining) suggests that adaptations to segregate mercury may be relatively inexpensive. Refineries should take responsibility for determining where mercury contained in crude oil is concentrated in refinery products and byproducts. The use of the supplementary environmental project (SEP) enforcement mechanism to require process modifications and related efforts to prevent mercury pollution should be considered when and if any enforcement steps are necessary regarding oil refineries.

## **Research, Development, and Monitoring Options**

Additional testing of distillate fuels is recommended using qualified state-of-the-art protocols and laboratories. A recent study has reported that mercury concentrations in crude oils range over 5 orders of magnitude, with a mean of 1.5 ppm.<sup>25</sup> This study did not report additional data on refined fuels. However, the variability of the mercury content of crude oils emphasizes the need for more data regarding mercury content of fuels and other refinery products and byproducts. Additional data will establish more certainty in the State's mercury inventory. Refinery processes should be investigated to determine ways to separate mercury from fuel products and further concentrate mercury in byproducts, as discussed above. EPA and the oil refining industry should be encouraged to implement further analyses and possible process improvements.

## **Outreach and Educational Options**

Facilitate communications between the regulatory, scientific, and engineering communities, the petroleum industry, and fuel-using sectors.

## **Recommendations**

- Promote energy conservation as a pollution prevention tool.
- Additional testing of distillate fuels using qualified procedures and laboratories.
- Investigate refinery processes to determine ways to separate mercury from products.

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<sup>25</sup> Bloom, N.S., 2000, Analysis and stability of mercury speciation in petroleum hydrocarbons, *Fresenius J. Anal. Chem.*, 366, 438-443.

## Fuel Oil Combustion: Residual (Including #4 and #6 Fuel Oil)

### Identification and Description of Source

Residual oil (number 6 fuel oil) is composed of the heaviest components of crude oil. It can be thought of as that portion of the crude oil that is left over when all other products are removed, hence the name “residual.” It is believed that a majority of the residual oil consumed in the United States is imported. Mercury is thought to exist as a contaminant in residual oil. It is assumed that all mercury present in residual fuels will be released into the atmosphere during the combustion process. Most residual oil is burned to generate electricity or to provide power to relatively large industrial processes. It is also the prime fuel source for ocean-going ships.

### Quantity and Estimated Uncertainty

Several stack tests have been performed in New Jersey on an electricity-generating unit burning residual oil.<sup>26</sup> The reported emission rate translates to a yearly emission of approximately 22 pounds if the facility was operating at full capacity. Based on an assumed thermal efficiency of this facility of 33%<sup>27</sup>, it would consume the equivalent of about  $4.1 \times 10^6$  megawatt hours of fuel (about 2.3 million barrels) if it operated at the tested rate for an entire year.<sup>28</sup> With an emission of 22 pounds of mercury per 2.3 million barrels (about 760 million pounds<sup>29</sup>) burned, the mercury concentration of the fuel can be estimated to be about 29 ppb. In 1997, New Jersey consumed about 9,348,000 barrels, or 58.8 trillion Btu, of residual oil.<sup>30</sup> This is equivalent to about  $1.72 \times 10^7$  MWH.<sup>31</sup> Extrapolation of these stack test data to the entire state thus results in an estimated emission of 88 pounds of mercury from the combustion of residual oil. Because of the limited data available, there is considerable uncertainty in this value.

This value is higher than the estimated emission from the combustion of distillate fuels (see separate source write-up). Such a value is consistent with a finding of higher levels of mercury in residual oils, found to be in the range of 4 ppb in another recent study,<sup>32</sup> than in other refined fuels. It is also consistent with a report that suggests significant emissions of mercury from facilities burning residual oil in Florida.<sup>33</sup>

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<sup>26</sup>. Klein, Michael, 1998, Memo from M. Klein, NJDEP to E. Choromanski, NJDEP. 12/23/98.

<sup>27</sup> 33% is typical of the thermal efficiency range of most large boilers.

<sup>28</sup>. The facility was operating at its capacity of 156 megawatts. Assuming 33% thermal efficiency and operation for 8760 hours, this facility would consume the equivalent  $156 \times 3 \times 8760$  megawatt hours of fuel, or  $4.10 \times 10^6$  MWH.

<sup>29</sup>. The conversion factor used is one barrel of residual weighs 331 pounds.

<sup>30</sup>. USDOE, 1997, State Energy Data Report for New Jersey, U.S. Department of Energy, Energy Information Administration, downloaded from <http://www.eia.doe.gov/lpub/state.data/data>, December, 1999.

<sup>31</sup>. The conversion factor used is  $2.928 \times 10^{-7}$  MWH per Btu.

<sup>32</sup>. Gilkeson, John, 1999, Mercury in Petroleum Refining: Crude Oil and Refined Products, Final Report to Legislative Commission on Minnesota Resources, DRAFT, Minnesota Office of Environmental Assistance, August 20, 1999.

<sup>33</sup>. Dvonch, J. T., J. R. Graney, G. Keeler, and R. Stevens, 1999, Use of elemental tracers to source apportion mercury in south Florida precipitation, *Environ. Sci. Technol.*, 33, 4522-4527.

## **Sectors Affected**

Residual oil is consumed in large boilers at utilities, commercial and industrial facilities. Facilities affected by this source category would include electric power generation, refining and large industrial facilities producing steam or electricity (for internal use).

## **Receiving Media**

Since this is a combustion process with no air pollution control to catch any mercury, the primary receiving medium is air.

## **Chemical Species**

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species such as  $\text{HgCl}_2$ , and species bound to particles are present. It is also possible that some methyl mercury is emitted. Fossil fuel combustion conditions create a milieu rich with methyl radicals,<sup>34</sup> and, from an energetic perspective, free radical reaction to produce  $\text{RHgX}$  is feasible.<sup>35</sup> The species emitted have not been confirmed through rigorous analysis or testing.

## **Reduction Options and Associated Costs and Impediments**

Any effort that will reduce energy usage will have the collateral effect of lessening the impact of this category. No specific reduction options are proposed, however, because of the relatively low mercury concentration of this source. Because of required product changes in the future, refinery processes will evolve. Evolution of oil refining processes may indicate ways to separate mercury from fuel products and further concentrate mercury in byproducts, which might be treated for mercury removal or disposed in ways that would not release mercury to air or water. The likelihood that mercury accumulates in the heavier liquid or solid products or byproducts (see discussion on oil refining) suggests that adaptations to segregate mercury may be relatively inexpensive. Refineries should take responsibility for determining where mercury contained in crude oil is concentrated in refinery products and byproducts. The use of the supplementary environmental project (SEP) enforcement mechanism to require process modifications and related efforts to prevent mercury pollution should be considered when and if any enforcement steps are necessary regarding oil refineries.

## **Research, Development, and Monitoring Options**

Additional testing of residual fuels is recommended using qualified state-of-the-art protocols and laboratories. A recent study has reported that mercury concentrations in crude oils range over 5 orders of magnitude, with a mean of 1.5 ppm.<sup>36</sup> This study did not report additional data on refined fuels. However, the variability of this mercury content emphasizes the need for more

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<sup>34</sup>. Glassman, I., 1996, Chapter 3, pp. 90-94, The Oxidation of Methane, in *Combustion*, 3<sup>rd</sup> Edition, Academic Press, San Diego.

<sup>35</sup>. DeNoble, James P., 1999, Critical Review: *Atmospheric Methylmercury: Sources, Sinks, and Inferences for its De Novo Generation*, DRAFT Masters Thesis, Rutgers University, October, 1999.

<sup>36</sup> Bloom, N.S., 2000, Analysis and stability of mercury speciation in petroleum hydrocarbons, *Fresenius J. Anal. Chem.*, 366, 438-443.

data regarding mercury content of fuels and other refinery products and byproducts. Additional data will establish more certainty in the State's mercury inventory. Refinery processes should be investigated to determine ways to separate mercury from fuel products and further concentrate mercury in byproducts, as discussed above. EPA and the oil refining industry should be encouraged to implement further analyses and possible process improvements.

### **Outreach and Educational Options**

Facilitate communications between the regulatory, scientific, and engineering communities, the petroleum industry, and fuel-using sectors.

### **Recommendations**

- Promote energy conservation as a pollution prevention tool.
- Encourage a national program for residual fuel testing.
- Consider stack controls on any large identified sources to capture mercury.

## **Gasoline Combustion**

### **Identification and Description of Source**

Gasoline is a complex mixture of hydrocarbons having a boiling range between 100° and 400° F. Components are blended to promote high antiknock quality, ease of starting, quick warm-up, low tendency to vapor lock and low engine deposits. Components in New Jersey are also produced and selected to meet the reformulated fuel requirements of the Federal Clean Air Act Amendments of 1990.

Mercury is thought to exist as a trace contaminant in gasoline. It is assumed that all mercury present in gasoline will be released into the atmosphere during the combustion process.

### **Quantity and Estimated Uncertainty**

No testing has been performed to quantify the total emissions from this source in the state of New Jersey. As with other analyses of mercury content of fuels, values reported in the literature based on studies that pre-date the use of ultra-clean laboratory techniques are considered suspect. Ultra-clean techniques, essential for accurate analyses of media containing low levels of mercury, did not become widely used until around 1990. Some analytical laboratories still do not use these techniques. Recent analyses of the mercury content of gasoline, have shown consistently low values, in the range of 1 ppb.<sup>37,38</sup>

The weighted average of 11 samples reported in the studies noted above and one other recently reported value of 20 ppb<sup>39</sup> is approximately 2.6 ppb. It is reported that 88,850,000 barrels of gasoline were consumed in New Jersey in 1997.<sup>40</sup> This is equivalent to about  $2.3 \times 10^{10}$  pounds.<sup>41</sup> Multiplying this quantity by the estimated concentration of 2.6 yields an estimated emission from this source of 60 pounds per year. Because of the limited data available, there is considerable uncertainty, perhaps of the order of 75% or more, in this value. If the actual values are closer to the upper end of the range, 20 ppb, the yearly emission could approach 460 pounds.

### **Sectors Affected**

Gasoline is consumed in great quantities in New Jersey by mobile sources. All public and private sectors are therefore affected by this source category.

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<sup>37</sup> Gilkeson, John, 1999, Mercury in Petroleum Refining: Crude Oil and Refined Products, Final Report to Legislative Commission on Minnesota Resources, DRAFT, Minnesota Office of Environmental Assistance, August 20, 1999.)

<sup>38</sup> Liang, L., M. Horvat, and P. Danilchik, 1996, A novel analytical method for determination of picogram levels of total mercury in gasoline and other petroleum based products, Science of the Total Environment, 187, 57-64.

<sup>39</sup> Florida DER, 1992, Florida Department of Environmental Regulation, 1992; Mercury Emissions to the Atmosphere in Florida, final report, Florida DER, 2600 Blair Stone Rd., Tallahassee, FL 32399.

<sup>40</sup> USDOE, 1997, State Energy Data Report for New Jersey, U.S. Department of Energy, Energy Information Administration, downloaded from <http://www.eia.doe.gov/pub/state.data/data>, December, 1999.

<sup>41</sup> The conversion factor of 258 pounds per barrel is used.

## Receiving Media

Since this is an uncontrolled combustion process as far as mercury is concerned, the primary receiving medium is air. Because of the large volume of gasoline used in the state, the misuse or accidental release of gasoline could impact other media such as water and land, and the resulting cleanups could impact disposal sites. It is not known whether catalytic converters on motor vehicles could capture any mercury in the exhaust, and if so, whether any mercury so captured might remain at the time of vehicle disposal.

## Chemical Species

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species such as  $\text{HgCl}_2$ , and species bound to particles are present. It is also possible that some methyl mercury is emitted. Fossil fuel combustion conditions create a milieu rich with methyl radicals,<sup>42</sup> and, from an energetic perspective, free radical reaction to produce  $\text{RHgX}$  is feasible.<sup>43</sup> The species emitted have not been confirmed through rigorous analysis or testing.

## Reduction Options and Associated Costs and Impediments

Any effort that will reduce energy usage will have the collateral effect of lessening the impact of this category. No specific reduction options are proposed, however, because of the relatively low mercury concentration of this source. The issues of vehicular fuel and transportation options are beyond the scope of the Task Force's efforts. Because of required product changes in the future, refinery processes will evolve. Evolution of oil refining processes may indicate ways to separate mercury from fuel products and further concentrate mercury in byproducts, which might be treated for mercury removal or disposed in ways that would not release mercury to air or water. The likelihood that mercury accumulates in the heavier liquid or solid products or byproducts (see discussion on oil refining) suggests that adaptations to segregate mercury may be relatively inexpensive. Refineries should take responsibility for determining where mercury contained in crude oil is concentrated in refinery products and byproducts. The use of the supplementary environmental project (SEP) enforcement mechanism to require process modifications and related efforts to prevent mercury pollution should be considered when and if any enforcement steps are necessary regarding oil refineries.

Add-on controls on engines are not proposed because of the low mercury concentrations and relatively low total amount of mercury from this source category. The costs associated are not defined.

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<sup>42</sup> Glassman, I., 1996, Chapter 3, pp. 90-94, The Oxidation of Methane, in *Combustion, 3<sup>rd</sup> Edition*, Academic Press, San Diego.

<sup>43</sup> DeNoble, James P., 1999, Critical Review: *Atmospheric Methylmercury: Sources, Sinks, and Inferences for its De Novo Generation*, DRAFT Masters Thesis, Rutgers University, October, 1999.



## **Research, Development, and Monitoring Options**

Additional testing of gasoline is recommended using qualified state-of-the-art protocols and laboratories. Mercury concentrations in gasoline may change due to ongoing efforts to reformulate this fuel, although the concentrations are likely to remain relatively low. A recent study has reported that mercury concentrations in crude oils range over 5 orders of magnitude, with a mean of 1.5 ppm.<sup>44</sup> This study did not report additional data on refined fuels. However, the variability of this mercury content of crude oils emphasizes the need for more data regarding mercury content of fuels and other refinery products and byproducts. Refinery processes should be investigated to determine ways to separate mercury from fuel products and further concentrate mercury in byproducts, as discussed above. EPA and the oil refining industry should be encouraged to implement further analyses and possible process improvements. The feasibility of developing exhaust gas controls that capture mercury should be investigated if future data indicate mercury emissions from gasoline combustion are significant.

## **Outreach and Educational Options**

Communications between the regulatory, scientific, and engineering communities, the petroleum refining industry, and fuel-using sectors should be facilitated.

## **Recommendations**

- Promote energy conservation as a pollution prevention tool.
- Encourage a national program for gasoline fuel testing.
- Encourage a statewide sustainable development program with a transportation and energy policy that reduces emissions of mercury and other pollutants.
- Consider development of exhaust pollution control devices that capture mercury.

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<sup>44</sup> Bloom, N.S., 2000, Analysis and stability of mercury speciation in petroleum hydrocarbons, *Fresenius J. Anal. Chem.*, 366, 438-443.

## **Natural Gas Combustion**

### **Identification and Description of Source**

Natural gas is a major fossil fuel source. It is used in utility and industrial boilers and combustion turbines, as well as in home and commercial home heating and water heaters.

### **Quantity and Estimated Uncertainty**

At point of combustion, natural gas contains only trace quantities of mercury.<sup>45</sup> The 1997 EPA Mercury Report to Congress estimates that the national emission rate of mercury from utility boilers burning natural gas is 0.002 tons/year, or 4 pounds per year.<sup>46</sup> This estimate is based on 1994 -1995 data. Because the numbers are so low, EPA did not estimate the emission rates from industrial, commercial or residential users of natural gas. Pro-rating the national mercury emission rate due to natural gas to New Jersey results in a negligible quantity.

### **Sectors Affected**

Utilities, industry, commercial and residential users of natural gas.

### **Receiving Medium**

Since this is an uncontrolled combustion process as far as mercury is concerned, the receiving medium is air.

### **Chemical Species**

The chemical species emitted from combustion of natural gas are unknown. Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as  $\text{HgCl}_2$ , and species bound to particles are present.

### **Reduction Options and Associated Costs and Impediments Research, Development, and Monitoring Options Outreach and Educational Options**

None. Emission rates are low.

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<sup>45</sup>. Phannenstiel, L., McKinley, C., and J. Sorenson, 1976; Mercury in natural gas, presented at American Gas Association, Operational Section Transmission Conference, Las Vegas, NV, 76-T-12, p. T-202.

<sup>46</sup>. USEPA, 1997, Mercury Study Report to Congress, Volume II; An Inventory of Anthropogenic Mercury Emissions in the United States, EPA-452/R-97-004, December, 1997.

## Petroleum Refining

### Identification and Description of Source

Oil refineries do not produce mercury. Mercury is a contaminant in the crude oils used as a raw material source for the production of fuels. Due to the very large volumes of petroleum processed mercury releases could be substantial even if the concentrations of mercury in petroleum were very low.

### Quantity and Estimated Uncertainty

As part of a comprehensive study of crude oils voluntarily undertaken by 5 of the 6 refineries in New Jersey, representative samples were taken on types of crude used as raw material, based on geographic location. These samples were analyzed by two laboratories that employ what are considered to be state-of-the-art procedures.<sup>47</sup> These same two laboratories were also used in another study of crude oil carried out in Minnesota.<sup>48</sup> The two laboratories used similar analysis procedures, but somewhat different extraction procedures to liberate mercury from crude oil and products. One laboratory, Cebam Analytical, Inc., used thermal decomposition to liberate the mercury; the other laboratory, Frontier Geosciences, Inc., employed a chemical extraction procedure using hot bromine monochloride. Both laboratories used cold vapor atomic fluorescence detection. As in the referenced Minnesota study, results from Cebam Analytical, Inc. were generally somewhat higher than from the other laboratory. The Minnesota researchers considered that Cebam Analytical, Inc. may have been more successful at liberating mercury from the samples, and concluded that use of the results of this lab represented both a worst case and a best estimate of the actual value. It is possible that the difference in values reported by the two laboratories represents a portion of mercury that exists in the crude oil and product samples in a chemically stable state, perhaps in the form of an organic complex.

In the study of the New Jersey refineries crude oil, the mercury concentration values reported by Cebam Analytical, Inc. have a mean 3.1 ppb, while the Frontier Geosciences, Inc. values have a mean of 1.5 ppb. In agreement with the conclusion of the Minnesota researchers, the results from Cebam Analytical, Inc. are considered to be both the worst case and best estimate of the total mercury content of the crude oil processed in New Jersey. When the individual analytical results from the various crudes used by each refinery are coupled with the quantities of these crudes processed, it is estimated that a total of approximately 270 pounds of mercury are contained in the crude that flows through New Jersey refineries each year. An inventory by refinery is included as a spreadsheet that is available from the Department.<sup>49</sup> The estimated uncertainty based on the data reported is considered to be modest, perhaps plus or minus 25%. However, it is likely that other crude oils have mercury concentrations that differ significantly from those reported in the New Jersey and Minnesota studies. A recent analysis of 76 samples of crude oils and condensates found that the mercury concentrations ranged over 5 orders of

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<sup>47</sup> Cebam Analytical, Inc., 3927 Aurora Ave. N., Seattle, WA 98103; and Frontier Geosciences, Inc., 414 Pontius North, Seattle, WA 98109.

<sup>48</sup> Gilkeson, John, 1999, Mercury in Petroleum Refining: Crude Oil and Refined Products, Final Report to Legislative Commission on Minnesota Resources, DRAFT, Minnesota Office of Environmental Assistance, August 20, 1999.)

<sup>49</sup> Contact Michael Aucott, NJDEP, DSR&T, [maucott@dep.state.nj.us](mailto:maucott@dep.state.nj.us), 609-292-7530.

magnitude, from 49.4 ppm, with a mean of 1.5 ppm.<sup>50</sup> Other reports suggest that crudes from Southeast Asia<sup>51</sup> and California<sup>52</sup> may have a higher mercury content than the crudes refined in New Jersey, which are mainly from Western and Northern Africa, the North Sea, South America, and the Arabian Peninsula.

### **Sectors Affected**

Refineries themselves are the only sector affected. Sources from combustion of the refined fuels produced by refineries are discussed in sections devoted to these fuels.

### **Receiving Media**

The disposition of the mercury in the crude could be air, land, or water. It could find its way to disposal sites for refinery byproducts or become part of the products of the refinery such as diesel fuel or gasoline. Based on limited data on fuel gases used during the processing of these low mercury crudes, air emissions are below the de minimus level of 2 lbs./yr. required for inclusion in air permits.<sup>53</sup> Available data on API (American Petroleum Institute) separator thickener tank solids (primary wastewater treatment sludge) disposed off site by one refinery indicated that this waste shipped off-site in 1998 for incineration by a cement kiln contained an estimated 22 pounds of mercury.<sup>54</sup> RCRA type K waste sludge material from refinery operations, believed to be [presumably] oil/water separator sludge from a Pennsylvania refinery that was processed by a processor of sludge, was reported to be as high as 60 ppm.<sup>55</sup> Although data are still too limited for a firm conclusion, the relatively high mercury levels reported in these refinery waste sludge materials, and the mercury concentrations estimated to be present in residual oil (see separate source write-up) suggest that much of the mercury present in crude oil may concentrate in the heavier, less-volatile product and waste streams.

### **Chemical Species**

All testing was for total mercury; different mercury molecular species were not identified. Because the concentrations are near the detection level, speciation of the mercury in crude would be difficult with current analytic techniques. Also, the species existing in the crude might be different from the species in the medium through which the mercury leaves the refinery.

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<sup>50</sup>. Bloom, N.S., 2000, Analysis and stability of mercury speciation in petroleum hydrocarbons, *Fresenius J. Anal. Chem.* 366, 438-443.

<sup>51</sup>. Wilhelm, S. M., 1996, Technical Overview of Mercury Waste Issues in SE Asia and Options for Disposal, Society of Petroleum Engineers, Inc., PO Box 833836, Richardson, TX 75083-3836, downloaded from <http://www.hgtech.com/waste.htm>, 9/17/98.

<sup>52</sup>. Hansell, D. and G. England, 1997, Air Toxic Emission Factors for Combustion Sources Using Petroleum-based Fuels, Vol. 1., prepared for S. Folwarkow, Western States Petroleum Association, 2300 Clayton Rd., Suite 1440, Concord, CA 94520 and Karen Ritter, American Petroleum Institute, 2020 L Street, NW, Washington, DC 20005, October 17, 1997. This report provides a mercury emissions factor for crude/pipeline oil of  $1.0 \times 10^{-5}$  lb./MMBtu; calculations performed by M. Aucott, NJDEP, indicate that this factor corresponds to a total mercury content in the crude/pipeline oil of approximately 190 ppb.

<sup>53</sup>. Letter from Stephen Martini, Coastal Eagle Point Oil Company, to Richard Langbein, NJDEP, May 7, 1999.

<sup>54</sup>. Letter from S. Martini, Coastal, to R. Langbein, NJDEP, May 7, 1999.

<sup>55</sup>. Joel Leon, NJDEP, personal communication, December 10, 1999.

## **Reduction Options and Associated Costs and Impediments**

None are identified because of the lack of understanding of disposition of the mercury in the crude once it is processed. Also, refinery processes associated with the production of liquid fuels are in a state of flux because of clean air considerations. There are no data on the impact of these changes on the distribution of mercury within the process and products. Because of required product changes in the future, refinery processes will evolve. Evolution of oil refining processes may indicate ways to separate mercury from fuel products and further concentrate mercury in byproducts, which might be treated for mercury removal or disposed in ways that would not release mercury to air or water. The likelihood that mercury accumulates in the heavier liquid or solid products or byproducts (see discussion on distillate oil combustion) suggests that adaptations to segregate mercury may be relatively inexpensive.

It is reported that simple, low-investment feedstock treatment procedures have been developed that eliminate Hg (and also arsenic) impurities with high efficiencies.<sup>56</sup> Refineries should take responsibility for determining where mercury contained in crude oil is concentrated in refinery products and byproducts. The use of the supplementary environmental project (SEP) enforcement mechanism, which allows actions with environmental benefits to be carried out in lieu of fines, to require process modifications and related efforts to prevent mercury pollution should be considered when and if any enforcement steps are necessary regarding oil refineries.

Any efforts that will reduce energy usage will have the collateral effect of lessening the impact of this category by reducing the amount of petroleum processed each year.

## **Research, Development, and Monitoring Options**

The inventory of analytic data on crude oil, refinery waste streams, and refinery products should be updated by the year 2005. Much of the data in the literature regarding mercury in crudes based on studies that pre-date the use of ultra-clean laboratory techniques are considered suspect. Ultra-clean techniques, essential for accurate analyses of media containing low levels of mercury, did not become widely used until around 1990. Some analytical laboratories still do not use these techniques. All analytical work done in connection with the sampling of crude oil from New Jersey refineries as discussed herein was performed by laboratories using what are believed to be state-of-the-art methods, achieving very low detection limits. All future analytical work should be performed using latest methods and ultra-clean techniques.

A quantified determination of the fate of mercury in crude oil is needed, as is better understanding of how mercury concentrations in fuel products can be minimized.

## **Outreach and Educational Options**

There should be outreach to the refining industry to encourage a better quantification of the fate of mercury in crude oil and to determine how mercury concentrations can be minimized in fuel products.

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<sup>56</sup> Sarrazin, P., C. Cameron, Y. Barthel, and M. Morrison, 1993, Processes prevent detrimental effects from As and Hg in feedstocks, *Oil and Gas Journal*, Jan 25, 1993.

## **Recommendations**

- Investigate processes to determine ways to separate mercury from fuel products prior to distribution.
- By 2005, update the inventory of mercury in crude oil and its fate.
- Encourage reduced energy use by refineries and other energy users.

## Wood Combustion

### Identification and Description of Source

Wood and wood wastes may be burned for residential heating or as a commercial energy source. Mercury is expected to be present in wood in trace quantities from root uptake from soil, and deposition of airborne mercury to leaves, buds and bark. Waste wood may contain mercury (or other metals) in paints that had been applied to surfaces.

Wood stoves are enclosed wood heaters used as residential space heaters. There are five different types of wood stoves: (1) the conventional wood stove; (2) the non-catalytic wood stove (emission reducing technology); (3) catalytic wood stove; (4) the pellet stove; and (5) the masonry heater.

Fireplaces are used generally for aesthetic effects and secondarily as supplemental heating. Although wood is usually the fuel for fireplaces, coal and compressed wood “logs” may also be burned.

### Quantity and Estimated Uncertainty

Wood stoves and fireplaces operate at temperatures above the boiling point of elemental mercury. As a result, any mercury in the wood can be expected to be emitted with the combustion gases. Although some wood stoves use emission controls to reduce volatile organic compound and carbon monoxide emissions, the measures are not expected to affect mercury emissions.

USEPA has recommended that an emission factor of  $5.2 \times 10^{-6}$  lb. mercury/ton of wood be utilized when estimating mercury emissions from commercial wood-fired boilers.<sup>57</sup> Residential stoves and fireplaces could be expected to burn wood that is no higher in mercury. Therefore, use of the same emission factor is reasonable. In 1997, the US Department of Energy estimated that wood consumption for combustion in New Jersey was 604,000 cords for residential housing, while commercial use was estimated at 59,000 cords. Industrial use as cords was not available; however, consumption estimated at 17.9 trillion Btu was used for calculations.<sup>58</sup> The densities of wood vary depending on wood type and the moisture content of the wood. Generalized density

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<sup>57</sup> USEPA, 1997, *Mercury Study Report to Congress, Volume II: An Inventory of Anthropogenic Mercury Emissions in the United States*, EPA-452/R-97-004, December, 1997.

<sup>58</sup> USDOE, 1997, *State Energy Data Report for New Jersey*, U.S. Department of Energy, Energy Information Administration, downloaded from <http://www.eia.doe.gov/pub/state.data/data>, December, 1999.

conversion factors for hardwoods and softwoods expected to be burned in New Jersey result in an estimated density of 36 pounds per cubic foot of wood.<sup>59</sup>

Using these factors, and the fact that one cord is equal to about 79 ft<sup>3</sup>, emissions from residential,<sup>60</sup> commercial,<sup>61</sup> and industrial combustion<sup>62</sup> were calculated as 4.5 lbs./yr., 0.4 lbs./yr. and 5.4 lbs./yr., respectively. The estimated yearly total is 10 pounds.

### Sectors Affected

Those who burn wood in any sector could be affected by measures to control this source.

### Receiving Media

Any mercury found in wood will be volatilized and be emitted with the combustion gases through the exhaust stack into ambient air.

### Chemical Species

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as HgCl<sub>2</sub>, and species bound to particles are present.

<sup>59</sup> Factors to Convert Wood Volume (ft<sup>3</sup>) to Weight (lbs.)

	Forest type	Softwoods	Hardwoods
Northeast and Mid-Atlantic Region	Pines	23.6	33.8
	Spruce-Fir	23.0	32.8
	Oak-Hickory	23.3	39.7
	Maple-Beech-Birch	24.0	37.4
	Bottomland Hardwoods	28.7	36.2

<sup>60</sup> Wood Weight = 604,000 cords burned x 79 ft<sup>3</sup> x 36.0 lbs/ft<sup>3</sup> = 1,717,776,000 lbs., or 858,888 tons wood burned. 5.2 x 10<sup>-6</sup> lb. mercury/ton wood x 858,888 tons wood burned = 4.5 lb. estimated mercury emissions from residential wood combustion

<sup>61</sup> Wood Weight = 59,000 cords burned x 79 ft<sup>3</sup> x 36.0 lbs/ft<sup>3</sup> = 167,796,000 lbs., or 83,898 tons wood burned. 5.2 x 10<sup>-6</sup> lb. mercury/ton wood x 83,898 tons wood burned = 0.4 lb. estimated mercury emissions from commercial wood combustion.

<sup>62</sup> Cord usage information was not available for the industrial category; however, estimated energy consumption (17.9 trillion Btu) was used with appropriate conversion factors. 5.2 x 10<sup>-6</sup> lb. mercury/ton wood x 17.9 trillion Btu/yr. x lb./8600 Btu x 1 ton/2000lbs. = 5.4 lbs. mercury/year.



**Reduction, Research, Development and Monitoring; Outreach and Educational Options;  
and Associated Costs and Impediments**

Given the low total quantity, consideration of reduction options is not warranted.

## Cultural Uses

### Identification and Description of Source

A potentially widespread but little understood source of mercury involves cultural uses in Latino and Afro-Caribbean communities.<sup>63,64</sup> The Task Force invited a presentation by Dr. Arnold Wendroff of the Mercury Poisoning Project (Brooklyn, NY), who reported on studies underway in New York and recommended similar investigation in New Jersey. While the total amounts of mercury used are small on a state-wide or industrial scale, its use in small enclosed spaces creates the potential for very high direct exposures to individuals. The Task Force endorsed the need to obtain more information and develop at least informational, if not regulatory, approaches to reducing this avenue of exposure and possible outdoor, as well as indoor contamination.

### *Availability and Extent of Use*

In the United States, certain Afro-Caribbean and Latin American traditions incorporate the use of elemental mercury in folk medicine and cultural practice. Mercury is sold in most botanicas, stores specializing in herbal remedies and items used in various cultural practices including Santeria (Lukumi), Voodoo, and Espiritismo.<sup>65,66</sup>

Several surveys have attempted to characterize mercury use in Latino and Afro-Caribbean communities. In a survey of New York botanicas, 93% reported selling mercury (about one to four capsules per day). A survey of 115 botanicas in 13 cities in the U.S. and Puerto Rico found that 99 sold mercury<sup>67,68</sup>. A survey of 203 Caribbean and Latin American adults in the New York City area found that 44% of Caribbean and 27% of Latin American respondents reported using mercury.<sup>69</sup> However, an ATSDR study of Santeria practitioners in Hartford, Connecticut's Hispanic community found only 14% reported using mercury in the home. *Johnson*<sup>70</sup> looked more generally at folk medicine and cultural practices, finding use outside of Santeria. Similarly, *Zayas and Ozuah*<sup>71</sup> found that santeros (Santeria priests) were mentioned by store proprietors as the source of mercury recommendations less than 10% of the time.

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<sup>63</sup>. Pinn, A. *Varieties of African American Religious Experience*. Minneapolis: Fortress Press, 1998.

<sup>64</sup>. Many cultures have traditions involving potentially harmful chemical exposures. Consider, for example, the German *Sylvester* (New Year's Eve) tradition of *Bleigiessen*, which typically involves melting lead on a stove top, then pouring it into a basin of cold water, for the purpose of telling fortunes for the coming year.

<sup>65</sup>. Wendroff, A. (1990). Domestic Mercury Pollution, *Nature*, **347**: 623.

<sup>66</sup>. Zayas, L.H. and Ozuah, P. O. (1996). Mercury Use in Espiritismo: A Survey of Botanicas. *American Journal of Public Health*, **86**(1): 111-112.

<sup>67</sup>. Wendroff, A. (1990). Domestic Mercury Pollution, *Nature*, **347**: 623.

<sup>68</sup>. Johnson, C. (1999). "Elemental Mercury Use in Religious and Ethnic Practices in Latin American and Caribbean Communities in New York City," *Population and Environment*, **20** (5): 443-453.

<sup>69</sup>. Johnson, C. (1999)

<sup>70</sup>. Johnson, C. (1999)

<sup>71</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

## Uses

Mercury is typically sold in capsules that contain, on average, about 8 or 9 grams (0.3 oz.) of mercury<sup>72</sup>. The most common method of use reported by botanica personnel was carrying mercury on the person in a sealed pouch (48.8%) or in a pocket (31.7%) as an amulet, while sprinkling mercury in the home was mentioned by 29%. Proprietors reported that family members, friends, spiritualists, and card readers recommend mercury to store patrons to bring luck in love, money or health and to ward off evil.<sup>73</sup> A survey of Latin American and Caribbean New York residents<sup>74</sup> found that burning mercury in a candle, mixing it with perfume, or sprinkling it in the car were also frequently reported uses. Of 28 New York botanicas visited in another survey, 13 prescribed sprinkling mercury on the floor.<sup>75</sup> Mercury poisoning has also been documented in Mexican-American infants fed mercury as a folk remedy for gastroenteritis.<sup>76</sup>

## Impacts

As a result of these practices, living spaces may become contaminated with mercury. Removal of mercury from floorboards and carpets is difficult if not completely impractical.<sup>77</sup> These mercury practices are a direct source of contamination not only to the users and their families, but also to people living in adjacent apartments, and to any future residents of the premises. The extent of use is unknown, and the magnitude uncertain, but there is potential for high exposures in this sub-population.

Although this source of mercury has only recently come to the attention of public health officials, the potential liability to landlords is significant. In addition, much of the mercury used in folk medicine and cultural practice may be disposed of improperly. *Johnson*<sup>78</sup> found that 64% of mercury users in his study reported throwing mercury in the garbage, while 27% flushed it down the toilet and 9% threw it outdoors.

## Quantity and Estimated Uncertainty

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<sup>72</sup>. Wendroff, A. (1990). Domestic Mercury Pollution, *Nature*, **347**: 623.

<sup>73</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

<sup>74</sup>. Johnson, C. (1999)

<sup>75</sup>. (Wendroff, 1990).

<sup>76</sup>. Geffner, M.E. and Sandler, A. (1980). "A Folk Medicine Remedy for Gastroenteritis." *Clinical Pediatrics*, **19**(6): 435-436.

<sup>77</sup>. Smart, E. R. (1986). Mercury Vapour Levels in a Domestic Environment Following Breakage of a Clinical Thermometer. *Science of the Total Environment*, 57: 99-103.

<sup>78</sup>. Johnson, C. (1999)

An estimate of exposure was based on available data from New York City.<sup>79,80</sup> In New York 100-300 capsules were reported sold each day in 35 botanicas.<sup>81</sup> Based on 1990 census estimates of 720,000 Hispanics in New Jersey as opposed to 1.7 million in New York City (five boroughs), one can estimate that 13,000-38,000 capsules are sold in New Jersey each year, for a total of 100-350 kg (200-800 lbs.) of mercury. Of this, 10-30 percent (10-100 kg/year, or 20-200 lbs.) is intentionally sprinkled on the floor indoors.<sup>82,83</sup> Additional exposures through accidental spillage or breakage of capsules, or through other practices (such as burning mercury in an oil lamp) may also occur, but such events are reported less frequently.<sup>84,85</sup> A lower-bound estimate of exposure can be derived by assuming households use an average of 2 capsules per year (10 kg total, 8-9 g per capsule), resulting in 600 households (1200 individuals) exposed per year in New Jersey. An upper bound estimate of exposure can be derived from *Johnson*<sup>86</sup> who found 27 percent of Latin Americans interviewed reported using mercury. If 30 percent of these users<sup>87</sup> sprinkle it on the floor, approximately 60,000 New Jersey residents would be exposed. These estimates vary widely, and more data specific to New Jersey are required to refine these estimates and properly characterize the extent and severity of the problem.

### **Sectors Affected**

The residential sector is potentially affected.

### **Receiving Media**

Through the practices described herein, mercury could ultimately be released to air, wastewater, or the municipal solid waste stream.

### **Chemical Species**

It is believed that only elemental mercury is involved.

### **Research, Development, and Monitoring Options/Recommendations**

More studies are needed to characterize exposure among cultural users of mercury, to understand the perceptions of risk in Latino and Caribbean communities, and to develop effective interventions, including risk-communication materials that address the beliefs and behaviors specific to those communities.

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<sup>79</sup>. Johnson, C. (1999)

<sup>80</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

<sup>81</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

<sup>82</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

<sup>83</sup>. Johnson, C. (1999)

<sup>84</sup>. Johnson, C. (1999)

<sup>85</sup>. Zayas, L.H. and Ozuah, P. O. (1996)

<sup>86</sup>. Johnson, C. (1999)

<sup>87</sup>. (Zayas and Ozuah, 1996)

NJDEP and/or NJDHSS should participate or review the following research projects and utilize the information to enhance other activities.

1. Clinical studies to identify mercury levels in people, either studying the mercury-using community vs. control groups or Latino and Caribbean populations vs. other groups. Where possible, connections should be made to the sources of exposure.
2. Ethnographic research to identify the needs, beliefs, and exposure patterns in specific subpopulations, and to understand the frequency and extent of different uses, sales rates, mercury supply chains, etc. Participant observation should be a particularly effective research tool for this work.
3. Risk perception and risk communication research that evaluates the effectiveness of communication materials and outreach strategies, and provides input for improved designs for both.
4. Fate and transport studies of mercury in indoor air to better relate sources to exposure levels, and to develop reliable models to predict indoor concentrations. Air measurements in residences and botanicas to validate these models and measure typical exposure levels stemming from cultural and religious uses.
5. Epidemiology and toxicology studies aimed at understanding low-level health effects and the importance of dermal exposure.

The EPA Office of Research and Development (ORD), ATSDR, CDC and the National Association of City/County Health Officials (NACCHO) are just some of the agencies expected to support and monitor many of the research projects identified above.

Based on the results of EPA's recent study, develop/adopt a protocol for environmental monitoring that uses new screening instruments that have greater accuracy.

### **Outreach and Educational Options/Recommendations**

Because botanicas represent a critical link to health care services in Latino and Afro-Caribbean communities, it is important to recognize the role of botanicas in providing culturally congruent health interventions in their communities.<sup>88,89,90</sup> Any public health interventions to reduce mercury exposure must recognize the important role botanicas play as the first place many turn for general health care services in Latino and Caribbean communities, and work with spiritualists, santeros, and botanica proprietors in addressing the problem.

### **Community Outreach and Education**

NJDEP and NJDHSS will conduct a coordinated effort among state and local health departments and local community organizations to help inform mercury suppliers and the public about mercury's risks. Activities to be performed include:

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<sup>88</sup>. (Zayas and Ozuah, 1996)

<sup>89</sup>. Pasquali, E. A. (1986). Santeria: a religion that is a health care system for Long Island Cuban-Americans. *Journal of New York State Nurses Association*, **17**(1): 12-15.

<sup>90</sup>. Pasquali, E. A. (1994). Santeria. *Journal of Holistic Nursing*, **12**(4): 380-390

Distribute educational materials on mercury for use by state and local environmental and health departments and community groups. Materials include:

1. Draft brochure with general focus
2. Brochure developed by EPA that is specific to religious uses and is available in multiple languages
3. Provide sample labels for mercury (to be developed with input from EPA, ATSDR, CPSC, and community groups) and distributed with support from ATSDR's network to botanicas.

B. Contact publishers and authors of religious/spirituality books that contain mercury spells, to request inclusion of a specific note about the risks of using mercury and how to reduce risk in practice or a consideration of alternative spells that use non-toxic substances.

C. Develop and implement, along with assistance from ATSDR and EPA, an effective outreach strategy for local health departments, focusing on community-based organizations, schools, and businesses. Such a strategy should include:

2. Distribution of materials mentioned above
3. Presentations to local civic organizations
4. Answering health related questions and concerns at community coordination centers and public availability sessions
5. Providing training and materials for persons responding to community questions and concerns
6. Working with spiritual leaders to identify and encourage the use of non-toxic alternatives to mercury
7. Outreach to other community groups or organizations affected by mercury
8. Evaluation of the effectiveness of the outreach program

D. Send out the letter, once finalized and approved, in Attachment I to all local and state government contacts in area that are considered to be of concern.

### **Health-care Provider Outreach and Education**

1. NJDEP and NJDHSS, along with ATSDR, will work with district and local health departments, provide education to health professionals, including alternative or nontraditional health care providers. Building these relationships could result in enlisting some hospitals or clinics in clinical data gathering efforts. Health professional education includes:
2. Distribution of physicians resource guides (such as those developed by Connecticut DHS and New York City DOH)
3. Presentation of grand rounds at local hospitals
4. Direct consultation with health care providers
5. Distribution of educational materials such as the *Case Studies in Environmental Medicine* to all health care providers in impacted areas
6. Provide training for health professionals on the possible psychological effects of mercury exposure

## **Legislation Efforts**

1. New Jersey should develop and implement appropriate legislation and regulations that limit the sale of elemental mercury, except for medical and other approved uses, reflecting the NEWMOA model legislation.<sup>91</sup>

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<sup>91</sup> See <http://www.newmoa.org/prevention/mercury/programs>

## Fluorescent Lamps

### Identification and Description of Source

Fluorescent and high-intensity discharge (HID) lamps (except for low-pressure sodium lamps) contain mercury. Approximately 95% of the mercury-containing lamps used in the United States are linear fluorescent light tubes.<sup>92</sup> The remainder are either compact fluorescents or specialty lamps produced for commercial or municipal use, such as street lighting. These include mercury vapor lamps, metal halide lamps, high-pressure sodium lamps, and neon lamps. The following discussion focuses on linear fluorescent tubes.

The amount of mercury in linear tubes has declined significantly over the past 15 years. According to a January 2001 industry report, the average mercury content of 4-ft. lamps has been reduced from 48.2 mg in 1985 to 41.6 mg in 1990, to 22.8 mg in 1994, to 11.6 mg in 1999.<sup>93</sup> The majority of fluorescent lamps in service in the United States are T12 lamps (1.5 in. diameter), containing an average of 22 milligrams according to the latest data.<sup>94</sup> T8 lamps (1 in. diameter) are also available. Designed to be more energy-efficient due to reduced tube volume, T8s also contain less mercury - an average of 14 mg. (Increased energy efficiency can be expected to result in reduced mercury emissions from power generation facilities.)

Since 1995 average amounts of mercury in all tubes has declined due to the introduction of "low-mercury" bulbs (both T12 and T8) by all three major manufacturers. Low-mercury lamps contain less than 10 milligrams of mercury. Both Osram Sylvania and GE Lighting quote a range of mercury content for their low-mercury lamps. Philips maintains that proprietary technology allows them to control the amount of mercury better than their competitors.<sup>95</sup> No fluorescent bulbs currently on the market are mercury-free.

Based on most lamps' rated life of 20,000 hours, tubes being discarded today may be estimated to be about 5 years old, and hence may contain, on the average, about 20 mg of mercury. Independent studies of lifetimes of available lamps have not been found. Variables affecting lamp life may include use patterns and types of ballasts used.

While EPA has published data on the total mercury content of the various types of 4-ft. fluorescent lamps, the agency states that the speciation is very uncertain.<sup>96</sup> The form of mercury in fluorescent lamps depends on a number of factors such as the age of the lamp, the type of lamp, and the method of lamp operation. At room temperature, less than 0.02 mg is in the elemental vapor state, about 0.1 mg is in the form of solid chemical compounds such as mercury oxide (HgO), and the balance is present as elemental liquid mercury distributed on the surface of

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<sup>92</sup> Northeast States for Coordinated Air Use Management (NESCAUM), et al., 1998, *Northeast States/Eastern Canadian Provinces Mercury Study, A Framework for Action*, February, 1998, p. VII-5.

<sup>93</sup> National Electrical Manufacturers Association (NEMA), *Fluorescent Lamps and the Environment*, <http://www.nema.org/lamprecycle/nemafluorfinal.pdf>.

<sup>94</sup> Walitsky, Paul, Philips Electronics, Inc., personal communication, February, 2001.

<sup>95</sup> Walitsky, Paul, Philips Electronics, Inc., personal communication, February 27, 2001

<sup>96</sup> U.S. Environmental Protection Agency, 1998. *Mercury Emissions from the Disposal of Fluorescent Lamps, Revised Model, Final Report*. Office of Solid Waste. Washington, D.C. March 31, 1998.



the phosphor and other internal parts. At lamp operating temperatures (approximately 40 degrees C) the amount of elemental mercury vapor increases, but does not exceed 0.05 mg.

Elemental mercury dispersed throughout the lamp exists as very small particles or beads that are typically too small to be seen with the naked eye.<sup>97,98</sup> Elemental mercury is introduced into the lamp during manufacture as a single charge, but becomes dispersed as the lamp operates because a certain amount of the mercury vaporizes each time the lamp heats up during operation, and then condenses into tiny droplets as the lamp cools.<sup>99</sup> As the lamp ages, an increasing amount of elemental liquid mercury is converted to solid mercury compounds (principally HgO). The quantity converted to HgO is between 1 and 4 mg at the end of the lamp's rated life.<sup>100</sup> A significant amount of the mercury originally present as elemental is also expected to become bound to the glass as the lamp ages.<sup>101</sup>

When mercury-containing lamps are broken, elemental mercury vapor, liquid mercury and phosphor powder containing adsorbed mercury can be released. In addition, small pieces of glass and other lamp components, such as aluminum end caps, will be contaminated with mercury and can release it to the environment if not managed properly.

Many of the fluorescent lamps in use in the United States today must be classified as hazardous waste when they are discarded because they fail the Toxicity Characteristic Leaching Procedure (TCLP) test used to categorize hazardous waste under the Resource Conservation and Recovery Act (RCRA). On the surface, it would seem that this requirement could direct mercury-containing lamps to an appropriate management facility and thus mitigate mercury releases from this source. However, the RCRA program has proven to be ineffective as a management system for fluorescent lamps for two primary reasons: 1) not all fluorescent lamp disposers are aware that their spent lamps may be hazardous waste and 2) millions of spent lamps are exempt from the RCRA regulations because they are disposed by households or conditionally exempt small quantity generators (CESQGs). CESQGs are businesses or facilities that are exempt from hazardous waste disposal requirements because they dispose of less than 100 kg of hazardous waste per month (300-350 4-ft. T12s or 400-450 4-ft. T8s). Both of these realities lead inevitably to the annual disposal of millions of spent fluorescent lamps through municipal and private waste collection systems.

EPA recognized that certain types of wastes, including certain used lamps, could be better managed under its Universal Waste Rule (UWR), first issued in 1995.<sup>102</sup> The rule was promulgated to facilitate proper collection, recycling and treatment of nickel-cadmium and other batteries, certain pesticides and mercury-containing thermostats that were classified as hazardous waste under the RCRA regulations. The UWR was also intended to establish a prototype system that could be expanded to include other wastes in the future. The 1995 rule did not include spent

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<sup>97</sup> Erdheim, Richard, National Electric Manufacturers' Association, personal communication, August 25, 2000.

<sup>98</sup> Bleasby, Peter, Osram Sylvania Corp., personal communication, August 25, 2000.

<sup>99</sup> Walitsky, Paul, Philips Electronics, Inc., personal communication, August 25, 2000.

<sup>100</sup> National Electric Manufacturers' Association (NEMA), 2000, NEMA, Rosslyn, VA.

<sup>101</sup> Walitsky, Paul, Philips Electronics, Inc., personal communication, August 25, 2000.

<sup>102</sup> USEPA, 60 FR 25542, May 11, 1995

lamps that were classified as hazardous waste. But after further consideration and study of the mercury issue, EPA issued a final rule on July 6, 1999 that added hazardous waste lamps to the federal list of universal wastes.<sup>103</sup> The addition of spent fluorescent lamps to the universal waste list was designed to encourage recycling of spent lamps and remove them from municipal landfills and incinerators, by eliminating some of the regulatory requirements (such as manifesting and transportation restrictions) that are assumed to deter businesses from proper disposal. Spent fluorescent lamps were added to the federal rule on January 6, 2000.

In December 1996, New Jersey adopted the federal UWR, managing certain batteries, thermostats and spent pesticides as universal wastes in the state.<sup>104</sup> These wastes were then designated as Class D recyclable materials and are managed under New Jersey's Recycling Rules (N.J.A.C. 7:26A). In that same year, the New Jersey Department of Environmental Protection (NJDEP) began a feasibility study to determine whether spent mercury-containing lamps (classified as hazardous waste) could be safely handled as universal wastes, and should be added to the New Jersey UWR.<sup>105</sup> The NJDEP identified five waste collection facilities to participate in the study, and the department monitored collection and handling activities over the period of the test. All test facilities collected discarded lamps, including the standard 4-foot fluorescent lamps, for recycling. The results of the NJDEP's evaluation were favorable. Amendments to the New Jersey UWR which will include mercury-containing lamps as universal wastes under the same terms as the federal rule are currently in the administrative review cycle within the NJDEP, with adoption expected in mid-2001.

One potential problem with exempting generators from RCRA requirements is that, although technically liable for future cleanup costs, etc., in practice these generators are likely to continue to dispose of tubes in the trash. Some disagreement exists as to how many generators—and how many lamps—are unregulated under the UWR. U.S. EPA estimates about 20 percent of generators are excluded under UWR; the California Environmental Protection Agency believes the number is much higher, at 40–50 percent.<sup>106</sup>

The NJDEP collected data from the five lamp-recycling or collection facilities that participated in the original feasibility study. This data, summarized below, represents the total amount of mercury, by linear feet of tubes, collected for the periods indicated.

Table 1: Linear feet of mercury-containing fluorescent tubes collected

Facility	Program Dates	Amount Recycled (linear feet)
Morris County Municipal Utilities Authority	03/97 – 02/99	302,366
Union County Municipal Utilities Authority	04/96 – 02/99	354,018
Burlington County Office of Solid Waste Management	05/96 – 02/99	112,508

<sup>103</sup> USEPA, 64 FR 36467, July 6, 1999

<sup>104</sup> 28 N.J.R. 5360

<sup>105</sup> New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste, Trenton, NJ

<sup>106</sup> Sustainable Conservation, *Reducing Mercury Releases From Fluorescent Lamps: Analysis of Voluntary Approaches*, prepared for the Bay Area Dischargers Association, September 2000, p. 21.

Public Service Electric & Gas Company	07/99 – 12/99	200,019
Global Recycling Technologies	07/99 – 01/00	1,319,288

Because the feasibility study results were favorable and because the EPA rule categorizing fluorescent tubes as universal waste is in effect, the NJDEP is allowing facilities to manage spent fluorescent lamps as universal waste while the regulations are in the administrative review phase. The NJDEP is requiring such activities to be carried out in strict adherence to the universal waste rules. Lamp crushing and other “processing” activities, viewed as treatment, are prohibited at any New Jersey facility that does not have a hazardous waste treatment permit that covers the processing activities. Broken fluorescent lamps must be handled as hazardous waste. Bulbs broken in transit or handling can be handled as a universal waste, provided the breakage amounts are incidental.

Fluorescent lamp recycling generally involves the crushing of intact lamps in a closed system, followed by heating, or “cooking,” in a retort/distillation unit to drive off residual mercury from the crushed components. Temperatures used in a typical retort/distillation unit are at or near 1,000° F.<sup>107</sup> Mercury released as vapor is collected for sale or reuse. After crushing, the phosphor powder, glass and metal produced is further treated one of two ways, depending on the recycling facility. One treatment method passes the crushed materials through a separator before treatment in a retort/distillation unit. The metal and glass components are collected without further treatment, and only the phosphor powder is fed to the retort/distillation unit for cooking. This process typically reclaims only about half of the mercury in the lamp, as much of it has become bound to the glass as the lamp ages. The second treatment process feeds all crushed lamp components to the retort/distillation unit, and separates the glass, metal and phosphor components after treatment. This process captures more than 99 percent of the mercury.<sup>108</sup> The materials produced by recycling facilities are not considered hazardous waste after treatment and are reused, if possible. The glass in the lamp can be recycled with other soda-lime glass, the mercury is recycled to new lamps or other manufacturing processes, and the aluminum is recycled with other aluminum like soda cans. The phosphor powder currently is not recycled because no significant use has been identified. It is important to distinguish between the two recycling methods because glass and metal lamp parts that have undergone mercury removal via the first method may contain residual mercury. This residual mercury may be released during manufacturing (by heating or washing) if the components are used to produce new products.

The cost of recycling fluorescent lamps is decreasing, and the industry foresees that it will continue to lower with increased demand for recycling and as technology for retorting larger batches of crushed lamps comes on line. In 1998, Osram Sylvania estimated that it costs approximately \$4,000 per pound to recover mercury through recycling.<sup>109</sup> In 2001, Bethlehem Apparatus stated that their per-lamp cost of mercury reclamation had come down to \$0.05 per 4-ft. tube for high-volume generators, from \$0.50 several years ago.<sup>110</sup> However, Osram Sylvania

<sup>107</sup> Lawrence, Bruce, President, Bethlehem Apparatus Company, Inc., personal communication, July 13, 2000.

<sup>108</sup> John Boyle, Bethlehem Apparatus Company, personal communication, March 13, 2001.

<sup>109</sup> Osram Sylvania, 1998, *Osram Sylvania – Position on Lamp Disposal Issues* (Press Release), January 26, 1998, Osram Sylvania, Danvers, Massachusetts.

<sup>110</sup> Ibid.

estimated in 1998 that the value of recycled mercury suitable for use in fluorescent lamp manufacturing was between two and three dollars per pound. As lamp manufacturers continue to reduce the mercury content of the fluorescent lamps they produce, the recovery cost per unit (or per pound of mercury) may increase further. Thus, the economics of recycling will not be an incentive to recycle fluorescent lamps. However, the avoided cost of either disposing of mercury-containing products as hazardous waste or removing mercury from trash incinerator emissions - as well as the public's insistence on removing mercury from the environment - may be the operative factors for this industry

### Quantity and Estimated Uncertainty

As stated above, the amount of mercury in a 4-ft. linear fluorescent lamp has declined from an average of nearly 50 mg in lamps manufactured in 1986 to an average 11.6 mg for lamps manufactured today<sup>111</sup>, with some low-mercury lamps containing less than 4 mg.<sup>112</sup> As noted above, it can be estimated that fluorescent tubes currently in the disposal stream contain an average of approximately 20 mg of mercury. Approximately 620 to 780 million lamps were discarded in the U.S. in 1999.<sup>113,114</sup> The mid-point estimate is 700 million lamps discarded. It can be assumed, based on population, that approximately 21 million lamps were discarded in New Jersey in 1999. If each lamp contains an average of 20 mg of mercury, the total mercury in lamps discarded in New Jersey is currently in the range of 925 pounds annually.

The fate of this approximately 925 pounds of mercury is dependent on a number of factors, including disposal. It is estimated that between 13 and 15 percent of the lamps disposed in the U.S. are either recycled or disposed of as hazardous waste, and 85 to 87 percent are disposed in regular municipal solid waste (MSW).<sup>115,116</sup> In New Jersey, about 25 percent of MSW goes to incinerators, and the remainder is approximately evenly divided between deposition in out-of-state and in-state landfills.

It is virtually certain that fluorescent tubes disposed in regular MSW break before they reach their ultimate disposal site. The amount of mercury that is released from broken fluorescent lamps (i.e., volatile Hg releases) is the subject of some debate presently. EPA has used a volatilization rate of 6% to model the releases of mercury from fluorescent lamps.<sup>117</sup> However, Erdheim, on behalf of the National Electrical Manufacturers Association (NEMA), has suggested that mercury releases from lamps transported by garbage trucks and from recycling programs

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<sup>111</sup> Paul Walitsky, Philips Electronics Corp., personal communication, February 28, 2001.

<sup>112</sup> Nesting, David, Paul Walitsky, and Manuel Oomens, 2000, Non-hazardous fluorescent TL lamps, presented at meeting of Illuminating Engineering Society, Washington, DC, July 31, 2000 and in press, *Journal of Illuminating Engineering Society*, 2000.

<sup>113</sup> National Electric Manufacturers' Association (NEMA), 2000, *Environmental Impact Analysis: Spent Mercury-Containing Lamps*, NEMA, Rosslyn, VA.

<sup>114</sup> U.S. Environmental Protection Agency, June 30, 1997. *Mercury Emissions from the Disposal of Fluorescent Lamps - Final Report*. Office of Solid Waste. Washington, D.C.

<sup>115</sup> NEMA, 2000, *Environmental Impact Analysis*, p. 3.

<sup>116</sup> U.S. EPA, 1997

<sup>117</sup> U.S. EPA, 1997.

represents 1% of the mercury in the lamps.<sup>118</sup> Release of a much higher percentage of the mercury in discarded lamps has been suggested by a study for Oak Ridge National Laboratory by Lindberg, et al.<sup>119</sup> These researchers have issued preliminary figures from a Florida landfill study of mercury emissions that indicate mercury emissions from broken fluorescent lamps persist for at least a week and may represent 20% to 80% of the mercury in the lamps.

Preliminary results of a study carried out recently in New Jersey<sup>120</sup> are consistent with the low end of the range reported by Lindberg, et al. In the New Jersey study, used, discarded fluorescent tubes were broken inside a sealed container, and the rate at which the mercury was emitted was measured. Comparison of the emission rate with the reported original mercury content of the tubes indicates that at temperatures ranging from 40° to 85° F, between 15% and 45% of the mercury contained in a broken fluorescent tube will volatilize during a two-week period. The study also found that one-third to one-half of the mercury that escapes from broken tubes is released during the first six hours. It also found that, and shortly after breakage, mercury concentrations in the immediate vicinity of broken tubes are likely to exceed the OSHA workplace exposure limit of 0.1 mg/m<sup>3</sup> as well as EPA's reference concentration of 300 nanograms/m<sup>3</sup>. The preliminary results of the New Jersey study are consistent with a preliminary analysis of data collected during the operation of a commercial bulb-crushing system in Illinois, which suggests that between 10% and 20% of the mercury in fluorescent tubes was released during crushing operations.<sup>121</sup>

If all of the fluorescent tubes discarded in New Jersey break during handling, and if 15% to 45% of the mercury contained in these tubes escapes prior to these tubes' ultimate disposal, the air emission from broken lamps is in the range of 240 ± 125 pounds per year.

A rough materials accounting of the estimated 925 pounds of mercury contained in discarded fluorescent tubes in the year 2000 is presented in the Table titled Materials Accounting of Estimated 925 lbs./yr. Mercury in Discarded Fluorescent Tubes.

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<sup>118</sup> Erdheim, R. 1997. Letter to Northeast States for Coordinated Air Use Management from R. Erdheim, National Electrical Manufacturers' Association (NEMA). December 4, 1997. Rosslyn, VA.

<sup>119</sup> Lindberg, S. E., K. Roy and J. Owens (Oak Ridge National Laboratory), February 6, 1999. ORNL Sampling Operations Summary and Preliminary Data Report for PaMSWaD-I, Brevard County Landfill. (Publishing agency is not named).

<sup>120</sup> Aucott, M, M. McLinden, and M. Winka, NJDEP, Report in preparation, December, 2000.

<sup>121</sup> Swain, Edward, Minnesota Pollution Control Agency, personal communication, November, 2000.

**Table 2**  
Materials Accounting of Estimated 925 lbs./yr. Mercury in Discarded Fluorescent Tubes

Management method	Portion managed	Pounds Hg per year managed	Short-term release to Environment, lbs./yr.	Explanation of release quantity
Recycled or disposed as hazardous waste	14%	130	trace	emissions controls assumed
Disposed as municipal solid waste (MSW)	86%	795	240	Assumes 100% breakage during waste handling, and partial release of contained mercury <sup>122</sup>
			6	Released via incineration <sup>123</sup>
			<1	Released from landfills <sup>124</sup>
Totals	100%	925	<250	

### Sectors Affected

Actions to reduce emissions from lamp breakage in the course of disposal could involve a variety of sectors, including governmental waste management agencies, manufacturers and distributors of fluorescent lamps, waste handlers and recyclers. The actions could also include all those, including large and small businesses, public and private institutions, and residential households, that use and discard fluorescent tubes.

### Receiving Media

Mercury contained in fluorescent lamps that are disposed of in landfills and municipal solid waste incinerators can be released from these facilities in the form of air emissions, or in landfill leachate. The amount of mercury entering the environment from discarded lamps, once they reach their ultimate disposal site, is included in the total emissions from these source categories. See Table 2 above.

<sup>122</sup> Assumes about 30% of the approximately 720 lbs. entering the MSW stream is released during the two-week period that waste could be in the waste management processing system.

<sup>123</sup> Approximately 25% of the NJ MSW stream, 1.6 million tons, is incinerated in NJ yearly (see separate write-up on MSW combustion). MSW's mercury content is estimated as 2 ppm, which translates to 6400 pounds of mercury going to incinerators. Assuming 25% of the 500 lbs. of mercury not released from discarded tubes goes to incinerators, fluorescent tubes contribute about 2% of this mercury. Thus, about 2% of the yearly mercury emission from incinerators of about 300 pounds can be attributed to fluorescent tubes.

<sup>124</sup> Mercury emissions from NJ landfills are about 30 lbs./yr. It is assumed, as in note above, that 2% of this is contributed by fluorescent tubes.

Mercury released from broken lamps during the estimated one- to two-week period that discarded lamps are present in the waste management system before landfill cover or incineration is considered herein to be a gaseous air emission. Some of the phosphor powder material present inside lamps, to which some mercury binds as the tube ages, could also be released to the environment in particulate form.

### **Chemical Species**

Mercury releases from broken fluorescent lamps may be primarily elemental mercury vapor. Mercury in the phosphor powder is primarily divalent;<sup>125</sup> lamp breakage can cause the powder to separate from the glass and be deposited at the site of breakage.

### **Recommended Control Opportunities, and Discussion of Costs, Difficulties, Impediments**

As discussed above, it is estimated that most of the mercury emissions associated with fluorescent tubes occur when discarded lamps are broken during normal MSW disposal operations, and before the discarded lamps reach their ultimate disposal site. Currently, it is not feasible to prevent lamp breakage if lamps are disposed of in regular MSW. Therefore, at this time, control of mercury releases from fluorescent lamps can be best accomplished by assuring spent lamps are collected and sent to a recycling facility, rather than disposed in the municipal waste stream. To be effective, this recycling system must: 1) store and transport the lamps by means that assure they are not broken before arriving at the recycler's facility, and 2) recycle lamps at a facility that recovers mercury from the glass and aluminum caps as well as the phosphor powder.

Another option for managing discarded tubes may be possible. Because mercury emissions from landfills appear to be very low (see separate write-up on landfill gas), landfills may offer an opportunity for effective sequestration of mercury contained in products, including fluorescent tubes. However, for landfills to be considered as an appropriate disposal site for discarded fluorescent tubes, a system would have to be put in place to prevent breakage of tubes during transport, and to ensure appropriate, safe management of the tubes prior to burial in the landfill. It is unclear at this time whether such a system would be cost-effective when compared with alternative discarded tube management systems, i.e., disposal as hazardous waste and recycling. More data on the relative cost distribution between the collection/transport/handling step and the crushing/reclamation step in fluorescent tube recycling operations might shed light on whether an appropriate discarded tube management system involving landfills could be feasible.

### **Spot Replacement of HID Lamps**

Another method that could contribute to the reduction of mercury releases from spent mercury-containing HID lamps is to assure that only spent lamps are removed from service. Mercury-containing HID lamps should not be removed from service until they have reached the end of

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<sup>125</sup> Bleasby, Peter, Osram Sylvania Corporation, personal communication, July 11, 2000.

their useful service life. For example, in Paulsboro, New Jersey PSE&G operates a resource recovery facility to assure certain equipment and items removed from service are disposed properly. PSE&G uses this facility to implement a Lighting Residuals Management Program. This program consolidates, segregates and tests high-pressure sodium lamps from street light maintenance operations to limit the premature recycling of these lamps and to assure that spent or out-of-specification lamps are recycled. Other large users of HID lamps within New Jersey should be made aware of the economic and environmental benefits of this program and encouraged to implement similar programs.

### **Relamping Indoor Spaces for Energy Savings**

For linear tubes used indoors, changing large numbers of lamps—and, if appropriate, ballasts—at the same time may be effective in reducing energy consumption and avoiding significant mercury emissions from power plants. Rather than wait for individual lamps to flicker and burn out, and changing them one at a time, many facilities practice “group relamping” because it saves on labor costs as well. Energy savings are greatest when T8 lamps and new electronic ballasts replace older T12s operated with magnetic ballasts. A 34-watt T8 is as bright as a 40-watt T12. (Newer T12s may be 34 watts.) Additionally, many managers find spaces that are overlit as designed; fewer tubes, using even less energy, may be sufficient for the comfort and productivity of people working in the area.

Replacing old magnetic ballasts with electronic ballasts increases energy savings as magnetic ballasts add up to 15 percent additional wattage to the lamp. Electronic ballasts will not flicker or hum. T8 lamps require electronic ballasts to work properly.<sup>126</sup>

### **Outreach and Education**

Major outreach and education efforts, stressing toxicity of mercury, the importance of recycling/reclamation/retirement of mercury, and proper handling procedures for spent lamps, could reduce estimated releases. Use of low-mercury fluorescent lamps, which will also result in a significant decrease in the amount of mercury released from lamp breakage, should be encouraged.

### **Research, Development, and Monitoring**

Until mercury can be eliminated from fluorescent and HID lamps, information should be gathered to assess the number of fluorescent lamps that are disposed in New Jersey annually and the disposal methods used. This data can then be used to target industries and population segments for outreach and education pertaining to recycling and/or proper management of spent lamps.

Because of the potentially large mercury emissions from broken, discarded lamps in New Jersey (estimated herein to be in the range of 100 to 320 pounds per year) more data should be collected on mercury emissions from this source. Included in the data collection effort should be

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<sup>126</sup> Paul Walitsky, Philips Electronics Corp., personal communication, February 28, 2001.



development of a reliable way to estimate the quantities of discarded lamps managed by the various methods.

Incentives and funding from sources such as the New Jersey Commission on Science and Technology should be provided for research directed toward reducing or eliminating the use of mercury in fluorescent and high-intensity discharge light lamps.

### **Recommendations**

New Jersey should establish a statewide policy for the handling and disposal of fluorescent lamps. This policy should include the following elements:

- Encourage use of low-mercury lamps, beginning with Treasury's procurement policies for state agencies and facilities. Transition to low-mercury lamps, especially low-mercury T8 lamps (some of which contain as little as 3.6 mg mercury) will eventually result in a decrease in the amount of mercury released from breakage, incineration, and landfill disposal. This transition will produce collateral benefits because the T8 lamps consume less energy per lumen, and the energy savings will translate to reduced air emissions of mercury from electricity generation.
- Promote relamping with low-mercury, energy-efficient lamps, including replacement of magnetic ballasts with electronic ballasts, in order to reduce mercury emissions from power plants.
- Promote appropriate management of discarded mercury-containing lamps. Currently, such appropriate management includes only recycling and disposal as hazardous waste. It is possible that other management systems could be developed in the future that would include landfills as the ultimate disposal sites, provided that sufficient safeguards were in place to prevent tube breakage prior to burial, and provided that monitoring data continues to indicate very low mercury releases from landfills. When setting up or supporting mercury recycling programs, specify recycling technology that reclaims mercury from all parts of the lamp, including the glass.
- Following the recommendations of DEP, support classification of discarded fluorescent lamps as universal waste. Such classification will help minimize costs of managing discarded lamps appropriately. Consider adoption of further rules or legislation that would require at least some of the larger CESQGs to recycle discarded lamps or dispose of them as hazardous waste.
- Educate waste management contractors and staff about the hazards of handling broken tubes or any materials contaminated with mercury. Since mercury from broken lamps is initially released rapidly, it is important to minimize exposure of workers to broken lamps.

- Prohibit disposal at incinerators. Despite current effective controls on mercury emissions from incinerators, emissions could be reduced further by keeping mercury-containing wastes, including discarded fluorescent tubes, out of the waste stream.
- Encourage removal from service of spent mercury-containing HID lamps only. Mercury-containing HID lamps should not be removed from service until they have reached the end of their useful service life.<sup>127</sup> Note that this recommendation does not apply to fluorescent tubes used indoors.

### **Recommendations**

- Acquire better data on emissions of mercury from breakage of discarded lamps.
- Acquire better data on quantities of lamps disposed, by management method.
- Provide incentives and funding for research to reduce or eliminate mercury in lamps.

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<sup>127</sup> For example, in Paulsboro, New Jersey PSE&G operates a resource recovery facility to assure certain equipment and items removed from service are disposed properly. PSE&G uses this facility to implement a Lighting Residuals Management Program. This program consolidates, segregates and tests high-pressure sodium lamps from street light maintenance operations to limit the premature recycling of these lamps and to assure that spent or out-of-specification lamps are recycled. Other large users of fluorescent and HID lamps within New Jersey should be made aware of the economic and environmental benefits of this program and encouraged to implement similar programs.

## Industrial and Commercial Sources Not Elsewhere listed

### Identification and Description of Source

It is possible that significant quantities of mercury are released from unknown sources. If such sources exist, facility level materials accounting data may soon be available to identify these sources as a result of recently adopted lower reporting thresholds for mercury and other Persistent Bioaccumulative Toxic (PBT) substance. This lower threshold should also help refine previously collected data for other sources mentioned elsewhere in this report. This section will discuss mercury information available from both facility level *materials accounting* and *inventory* reporting.

### Facility Level Materials Accounting Data

Mercury and mercury compounds are listed on the federal Emergency Planning and Community Right to Know Act (EPCRA) Section 313 toxic chemical list, Toxic Release Inventory (TRI). Any New Jersey facility that manufactures or processes more than 25,000 lbs./yr. or otherwise uses more than 10,000 lbs./yr. of a listed hazardous substance is required to file a TRI report (Form R) with EPA with a copy to NJDEP quantifying the amount of material annually released to the environment. The manufacturing sector of the economy, which includes facilities in Standard Industrial Classification (SIC) codes 20 through 39, have been covered by TRI reporting since the programs inception in 1987. The Environmental Protection Agency expanded the scope of TRI reporting in 1997 to cover seven new industry sectors including metal mining (SIC code 10), coal mining (SIC code 12), electrical utilities that combust coal and/or oil (SIC codes 4911, 4931, and 4939), Resource Conservation and Recovery Act (RCRA) Subtitle C hazardous waste treatment and disposal facilities (SIC code 4953), chemicals and allied products wholesale distributors (SIC code 5169), petroleum bulk plants and terminals (SIC code 5171), and solvent recovery services (SIC code 7389). These newly covered facilities were required to report releases above the reporting threshold beginning July 1999 for reporting year 1998. There are no metal or coal mining facilities (SIC 10 and 12, respectively) currently operating in New Jersey.

In New Jersey, any facility required to file a federal TRI report is required to submit a Release and Pollution Prevention Report (RPPR) to the Department's Community Right to Know (CRTK) Program and is also required to perform pollution prevention planning. The notable exception is SIC code 7389 (solvent recovery services) which is not covered under the New Jersey Rules. Any facility which files at least one federal Form R is required to submit an RPPR for all TRI toxic substances which are manufactured, processed or otherwise used in excess of 10,000 lbs./yr. In addition to the release and off-site transfer data captured by the federal Form R, the Release and Pollution Prevention Report also collects facility level throughput data (annual quantities manufactured, consumed, brought on site, recycled on site and off site, shipped as or in products, as well as the amount generated as production related waste, also known as nonproduct output or NPO). Any New Jersey facility submitting an RPPR is required to develop a Pollution Prevention Plan designed to reduce the quantity of TRI substances used at the facility and or generated as nonproduct output. Covered facilities are also required to set

five-year reduction goals and to annually report progress made toward reaching the facility level five-year reduction goals.

While it is known that New Jersey businesses use and release mercury to the environment, very little data is available since few facilities exceed the 10,000 lbs./yr. reporting threshold. In December 1998, the Mercury Pollution Task Force provided NJDEP with an interim recommendation requesting that the Department amend its rules to lower the throughput reporting threshold of mercury from 10,000 lbs./yr. to 100 lbs./yr. Lowering the reporting threshold to 100 lbs./yr. would have provided the Department with more refined estimates regarding mercury usage and environmental releases. The Department had the statutory authority to lower the mercury reporting threshold to 100 lbs./yr. and began moving forward with the Task Force recommendation. However, the point soon became moot when EPA proposed its Persistent Bioaccumulative Toxic (PBT) substance rule in January 1999 and adopted an even lower 10 lbs./yr. reporting threshold for mercury later that year. The federal TRI amendments were immediately adopted by reference by the New Jersey Community Right to Know and Pollution Prevention Programs. Covered New Jersey facilities must submit Form Rs and RPPRs on July 1, 2001 reporting mercury throughput and release data for calendar year 2000 at the 10 lbs./yr. reporting threshold.

As a result of the lower threshold for mercury and mercury compounds, New Jersey will have a better understanding of the use and fate of mercury in the environment. In addition, any facility reporting mercury or mercury compounds to the CRTK program will also be required to perform pollution prevention planning. It is hoped that the pollution prevention planning process will assist facilities in finding ways to reduce or eliminate mercury use and releases.

### **Facility Level Inventory Data**

New Jersey's Worker and Community Right to Know Act also requires reporting of inventories of environmental hazardous substances, including mercury and a number of mercury compounds, from thousands of covered industrial, commercial, and institutional facilities on the Community Right to Know Survey<sup>128</sup>. This information provides clues as to how and where mercury may be used throughout the State. These data were reviewed to assess the amounts of mercury and mercury compounds present at reporting sites. Because the CRTK Survey requires reporting of quantities by the use of inventory range codes (e.g., code "09" is used for quantities less than one pound, code "10" for quantities from 1 to 10 pounds, code "11" for quantities from 11 to 100 pounds, etc.), actual quantities must be estimated. With the assumption that the median quantity of each range is the actual quantity represented by a code, totals for the various chemicals reported can be estimated. The 1991 CRTK Survey database indicates that several hundred facilities had on site a combined inventory of several hundred thousand pounds of mercury and various mercury compounds, including mercuric iodide, phenyl mercuric acetate, mercuric nitrate, mercuric sulfate, mercuric chloride, and mercury fulminate.

A review of 1999 CRTK Survey data, reflecting the higher 500 lbs./yr. threshold, was also conducted. Eight facilities were identified reporting mercury and or mercury compounds with an

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<sup>128</sup> NJDEP/BCRIP

annual inventory of between 10 and 100 pounds each, seventeen facilities reporting an inventory between 100 and 1,000 pounds, and three facility with inventories between 1,000 and 10,000 pounds. Two hospitals reported annual mercury inventories on the 1999 CRTK Inventory Survey in quantities ranging from 100 to 1,000 pounds. Six educational institutions reported annual mercury or mercury compound inventories including three elementary/secondary schools, two universities, and one technical school. Most of these educational institutions reported inventories ranging from one to ten pounds with the notable exception of one university reporting an annual inventory between 100 and 1,000 pounds. Three glass manufacturers reported an elemental mercury inventory ranging from 10 to 1,000 pounds, perhaps used as a calibration tool in the manufacture of volumetric laboratory glassware. Two scrap and waste material facilities each reported annual mercury inventories between 100 and 1,000 pounds. Mercury contained in scrap metal may be a potential source of contamination for iron and steel manufacturers as discussed in the *“iron and steel manufacturing and ferrous scrap processing”* section of this chapter.

The presence of these large quantities of mercury and mercury compounds on sites suggests that large uses of these substances may occur. Such large uses, if they occur, could be accompanied by large releases to the environment.

### **Quantity and Estimated Uncertainty**

The PBT Rule amended federal TRI and New Jersey RPPR reporting requirements and significantly lowered the reporting threshold for certain PBT substances, including mercury and mercury compounds. The final rule took effect December 31, 1999 for reporting year 2000. Under the new federal rules any facility which manufactures, processes or otherwise uses mercury or mercury compounds in excess of 10 lbs./yr. is required to file a TRI report. Release reporting requirements were also changed to require quantification of any release to the level of significant figures that the measurement techniques support. For mercury, releases will now be reported at or below one pound per release incident. The rules also eliminated the de minimis reporting exemption for PBT substances. Under the old rules facilities were allowed to disregard concentrations of hazardous substances contained in mixtures if a substance was present in the mixture at less than one percent. If the substance was listed as an OSHA carcinogen the de minimis level was reduced to less than 0.1 %. Depending upon the concentration of mercury in the raw material, facilities which annually throughput large quantities of raw material (e.g. iron and steel manufacturers, petroleum refiners and coal fired utilities) have the potential to release mercury into the environment in excess of the 10 lbs./yr. reporting threshold. Eliminating the de minimis limit will now capture these releases that would have otherwise gone unreported.

The 1991 CRTK Inventory Surveys reflect all mercury use by reporting facilities, since there was no reporting threshold in place at the time. A 500 lbs./yr. inventory reporting threshold was introduced in 1994 limiting the amount of information collected for mercury used or stored in small quantities. Some facilities continue to report quantities of mercury and other compounds on the CRTK Survey below the 500 lbs./yr. reporting threshold. The CRTK Survey requires reporting of quantities by the use of inventory range codes (e.g., code “09” is used for quantities less than one pound, code “10” for quantities from 1 to 10 pounds, code “11” for quantities from 11 to 100 pounds, etc.) rather than reporting the actual quantity present at the facility. The use of range codes makes it difficult to precisely estimate actual quantities stored at New Jersey

facilities. However, with the assumption that the median quantity of each range is the actual quantity represented by a code, totals for the various chemicals reported can be estimated.

### **Sectors Affected**

Any sector referenced above subject to federal TRI and New Jersey RPPR reporting and Pollution Prevention Planning requirements may potentially be affected by the lower mercury reporting threshold. The Department will have a better understanding of which facilities are affected when the RPPRs are reviewed in July 2001. Potentially affected facilities include those that burn large quantities of fuel oil and or coal, including ten coal fired electric generating utilities and six petroleum refineries in the state. Other potentially affected facilities include six iron and steel manufacturers, at least two aluminum processors, and electronic equipment manufacturers in the state. Facilities required to report CRTK Surveys of quantities of mercury and mercury compounds greater than 500 pounds are those that fall into the standard industrial classification (SIC) codes shown in Table 1.

Table 1.

### **Standard Industrial Classification Codes: New Jersey Employer Groups and Activities Subject to Hazardous Substances Reporting**

<u>SIC Code</u>	<u>ACTIVITY</u>
07*	AGRICULTURAL SERVICES
20 - 39	MANUFACTURING ESTABLISHMENTS
45*	TRANSPORTATION BY AIR
46	PIPELINES, EXCEPT NATURAL GAS
47*	TRANSPORTATION SERVICES
48*	COMMUNICATIONS
49	ELECTRIC, GAS, AND SANITARY SERVICES
50*	WHOLESALE TRADE - DURABLE GOODS
51*	WHOLESALE TRADE - NONDURABLE GOODS
55*	AUTOMOTIVE DEALERS AND GASOLINE SERVICE STATIONS
72*	PERSONAL SERVICES
75*	AUTOMOTIVE REPAIR, SERVICES, AND GARAGES
76*	MISCELLANEOUS REPAIR
80*	HEALTH SERVICES
82*	EDUCATIONAL SERVICES
87*	ENGINEERING, ACCOUNTING, RESEARCH, MANAGEMENT, AND RELATED SERVICES
91 - 96 Governments <sup>3</sup>	PUBLIC ADMINISTRATION - All State, County, and Local

\* indicates only a portion of the major group is covered

### **Receiving Media**

Receiving media are unknown at this time, but include air, water, land, landfills and products in general use throughout the state.

## **Chemical Species**

Chemical species include elemental mercury and various mercury compounds, including mercuric iodide, phenyl mercuric acetate, mercuric nitrate, mercuric sulfate, mercuric chloride, and mercury fulminate.

## **Reduction Options and Associated Costs and Impediments**

Specific reduction options cannot be specified at this time. New Jersey's Pollution Prevention Rule requires covered facilities to prepare Pollution Prevention Plans to reduce their use and nonproduct output of covered substances, including mercury and its compounds. The Rule also requires facilities to set five-year use and nonproduct output reduction goals. However, implementation of pollution prevention options identified in Pollution Prevention Plans is optional, as are facility level use and nonproduct output goals. Pollution prevention options may range from inexpensive administrative controls such as implementing best management practices and spill and leak prevention measures to more expensive process modification options requiring the installation of new equipment.

## **Research, Development, and Monitoring Options**

It is imperative that the Department review the Release and Pollution Prevention Reports and the Toxic Release Inventory as soon as possible after July of 2001, when the next iteration of these reports is received with the new 10 lbs./yr. threshold for mercury. Posting of facility level five-year reduction goals on the Department's web site will help make this information readily available to the community and enhance public awareness of mercury use in New Jersey.

## **Outreach and Educational Options**

The Department should continue its outreach to covered facilities, carried out by the Pollution Prevention and CRTK Programs, to ensure proper and accurate reporting.

## **Recommendations**

- The Department should continue to apply pressure on covered facilities to develop and implement quality Pollution Prevention Plans pursuant to the New Jersey Pollution Prevention Act, in order to achieve meaningful mercury use and release reductions.
- The Department should review the Release and Pollution Prevention Reports and TRI inventory as soon as possible after July 1, 2001, and use these reports as well as other sources to gain better a better understanding of mercury releases from these sectors.
- The Department should increase enforcement activities to ensure that all facilities which may potentially exceed mercury reporting thresholds for the RPPR and/or CRTK Survey have indeed reported.
- The Department should allocate sufficient resources to ensure enforcement activities and data

processing and analysis are completed in a timely fashion.

- The Department should post five-year facility level use and nonproduct output reduction goals on the Department's web site.
- The Department and EPA should continue outreach to covered facilities to promote pollution prevention.



## Iron and Steel Manufacturing and Ferrous Scrap Processing

### Identification and Description of Source

In New Jersey, there are three facilities that produce steel by melting scrap in electric arc furnaces and three facilities that produce cast iron from melting scrap in cupolas (vertical furnaces). The air pollution permit for each facility includes a mercury limit. In some cases these limits have been exceeded resulting in ongoing enforcement actions. Stack tests conducted pursuant to permit conditions at five of the six facilities have demonstrated that mercury emissions occur in the range of 1000 pounds per year.

In the three cupola furnaces and one of the electric arc furnaces, coke is mixed with metallic scrap to serve as a reducing agent to remove oxides. This coke is manufactured by heating high-grade bituminous coal (low sulfur and low ash) to around 1925° F in an enclosed oven chamber without oxygen. Mercury contained in the feed coal is probably driven out by the high temperatures of the coke manufacturing process. Therefore, it is likely that the mercury emitted by these facilities comes from the feedstock ferrous scrap.

The scrap includes recycled metals from discarded motor vehicles and home appliances, and waste metals from demolished building structures. It is known that mercury is used in a number of items that, when discarded, are likely to find their way into metallic scrap. For example, in the U.S. about 10 tons per year of mercury was used through the mid-90s in tilt switches (e.g., in trunk lights) and in anti-lock braking systems in automobiles. Mercury has also been extensively used in gas pressure regulators, switches and flame sensors in appliances.<sup>129</sup> Mercury switches are still used by some manufacturers, although a planned phase out by 2002 is reported.<sup>130</sup> Mercury is also used extensively in residential thermostats and in industrial equipment including thermostats, relays and other switches and control devices, and in measuring devices.

Existing stocks of such items, based on reported use quantities and estimates of service lives, are likely to be surprisingly large (see write-up on mercury-containing products in general use). For example, a recent study indicates there are 172-200 tons of mercury in switches in automobiles presently on the road in the U.S.<sup>131</sup> With 3% of the U.S. population, and somewhat more than 3% of the U.S. vehicle fleet, there would thus be between 10,000 and 12,000 pounds of mercury in switches in New Jersey's motor vehicle fleet alone. Since the average age of automobiles on the road is approximately 9 years,<sup>132</sup> it can be assumed that approximately 10% of the motor vehicle fleet is discarded yearly, implying that more than 1000 pounds of mercury from automobiles in New Jersey enters the scrap processing system each year.

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<sup>129</sup> Cain, Alexis, USEPA Region V, Contamination of Scrap Metal with Mercury: A Potentially Significant Source of Mercury Emissions, presented at the conference *Coordinating Mercury Reduction Programs: A Meeting of National and Local Government Officials*, Baltimore, MD, March 20-21, 2000.

<sup>130</sup> Corbett, Thomas, New York Department of Environmental Conservation, personal communication, July, 2000.

<sup>131</sup> Ecology Center, Great Lakes United, and U. of Tennessee Center for Clean Products and Clean Technology, *Toxics in Vehicles: Mercury*, January 2001, p. 7.

<sup>132</sup> U.S. Department of Transportation, 1998, National Highway and Traffic Safety Association, U.S. DOT, <http://www.nhtsa.dot.gov>, Washington, D.C.

It is important to note that while use of mercury switches in vehicles has declined significantly in recent years (62 to 77 percent since 1996), mercury use in anti-lock braking systems has increased over the same period by at least 130 percent and perhaps as much as 180 percent.<sup>133</sup>

Ferrous scrap is processed by a number of different industries and types of facilities. Discarded automobiles, for example, are first handled by wreckers who tow vehicles to storage areas. From there, high-value vehicles are transferred to any of several hundred automobile dismantlers operating in the state. When the useful parts, cast-iron parts, tires, liquids and other items have been removed by the dismantlers, the hulks are crushed, and then transported to one of several shredders operating in New Jersey and the surrounding area. Discarded automobiles of lower value, such as older vehicles and totaled wrecks, may go directly to a shredder. Shredding reduces the hulk to fist-sized pieces of metal. Other discarded metal items, including appliances, demolition debris, etc. also enter the scrap processing system at various points. Ultimately, the processed scrap is shipped out of state or used as feedstock for one of the state's iron or steel manufacturers. Some of the feedstock used by New Jersey manufacturers comes from out of state as well.

Mercury may be released to the environment at various points in the scrap processing system. For example, mercury-containing items such as thermostats and switches may not survive a shredding process intact.

### **Quantity and Estimated Uncertainty**

Stack test results are varied, but indicate significant emissions from the iron and steel manufacturing sector. Calculations using the permitted mercury emission for one facility, and the reported emission rates based on permitted hours of operation and the most recent stack tests for the other five facilities, gives an estimate in the range of 1000 lbs. of mercury per year. A spreadsheet available from the Department provides a summary of these data. The limited number of tests per facility and the lack of test results for one facility makes this estimate uncertain. However, this result corresponds with national data indicating that mercury air emissions from electric arc furnaces total 15.6 metric tons per year in the U.S., of which mercury from automobiles is likely the single largest contributing source.<sup>134</sup>

There are also some mercury emissions likely associated with the shredding process, and with the dismantling of automobiles and other discarded items. A mass balance of mercury at a mid-western electric arc furnace indicated that the mercury inputs to the facility were apportioned to outputs as follows: stack emissions, 31%; furnace silo dust; 49%; shredder fluff residue, 18%; and on-site auto shredder emissions, 2%.<sup>135</sup>

### **Sectors Affected**

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<sup>133</sup> Ecology Center, 2001

<sup>134</sup> Ibid., p. 36.

<sup>135</sup> Cain, Alexis, USEPA

The six large industrial facilities in this category would be affected by implementation of reduction requirements.

### **Receiving Media**

The primary receiving medium is believed to be air, from stack emissions at the facilities. There may be some mercury runoff to water and land contamination from outdoor scrap piles. There may be health effects to on-site workers from exposure to mercury.

### **Chemical Species**

The species of the emissions and suspected emissions are unknown, but, because the mercury used in switches, etc. is elemental, and because there is no direct combustion of the mercury-containing items during the steel and iron manufacturing processes, the emissions are probably also elemental.

### **Reduction Options and Associated Costs and Impediments**

Reducing mercury emissions from iron and steel manufacturers will undoubtedly require a multi-media, multi-sector pollution prevention approach, including removal of mercury from feedstock scrap. Such removal will necessitate: 1) elimination of mercury-added parts from new cars; and 2) removal of mercury switches from existing cars when they are dismantled or prior to shredding. Scrap management becomes the focus of source reduction efforts.

However, scrap processors report significant difficulty in obtaining information from automakers about the exact location of the switches in trunks and hoods. Auto manufacturers should take responsibility for facilitating removal of mercury from vehicles they have produced, both by providing information to dismantlers and scrap processors, and, if necessary, by providing resources to facilitate removal. Unfortunately, the regulatory burden at this time is falling on the iron and steel manufacturers and, to a lesser extent, on scrap yards where mercury spills are reported.

Analogous to New Jersey's Municipal Waste Incinerator rules, a performance standard for iron and steel manufacturers could be designed to reduce mercury emissions through a combination of aggressive pollution prevention, source separation, and available controls.

Periodic testing should be required. Frequency of testing should depend on the mercury emission level. Prior to setting a specific mercury emission limit, the Department should require testing of carbon injection to determine its effectiveness for iron cupolas and steel furnaces. Realistically, air pollution controls at iron and steel manufacturing facilities are likely to continue to be necessary in addition to mercury separation. The current use of baghouse air pollution control devices on one of the cupola furnaces and all three of the electric arc furnaces makes carbon injection a relatively low capital cost option for four of the six facilities. The two cupola furnaces with scrubbers would need to rely on scrap management or evaluate measures to remove mercury switches, or both. Scrubbers do remove some forms of mercury, but are less effective than carbon injection with baghouses. Measures to oxidize mercury prior to a scrubber

may substantively increase the mercury removal effectiveness of scrubbers. Removal of mercury from the scrubber residue and liquor would be needed.

Prior to implementation of stringent limits, however, iron and steel manufacturers, auto dismantlers, and scrap processors might be provided time to work with auto manufacturers to develop cooperative programs to reduce mercury in scrap. In two USEPA regions (Region 2 and Region 5), a “bounty” program for mercury is under discussion, based on the premise that if mercury had greater value it would be removed from scrap before ever reaching the smelters. Such a bounty, to be paid to dismantlers or shredders, could be funded by the auto manufacturers and/or iron and steel manufacturers. A pilot bounty program, including a significant research component, should be tested in an interstate region, since scrap autos are a highly movable commodity.

Recovery and recycling or retirement of mercury in vehicles would be greatly facilitated by designation of mercury-containing switches as Universal Waste in New Jersey and other states participating in a bounty program.

Because non-mercury-containing replacement switches are readily available for vehicle convenience lighting, state government and other fleet operators could replace mercury switches while cars are still in service. Purchasing specifications for new cars could require that mercury switches be exchanged for non-mercury switches before cars are delivered.

### **Research, Development, and Monitoring Options**

Testing of carbon injection should be performed to determine its effectiveness for iron cupolas and steel furnaces. Also, measures to increase the effectiveness of scrubbers should be evaluated.

A pilot bounty program should be designed to yield data about the optimum amount of the bounty, and the quantities of mercury that can be recovered from various points along the auto dismantling/scrap processing line.

More data are necessary on possible mercury releases associated with scrap metal shredding and other processing activities.

### **Outreach and Educational Options**

The importance of removing mercury-containing switches and other items should be communicated to automobile dismantlers and others in the recycled metal processing industry, fleet managers, governmental officials responsible for regulating motor vehicles, and the general public.

### **Recommendations**

- The federal government should require the rapid phase out of the use of mercury-containing products in new motor vehicles. Following the lead of other states, New Jersey should consider banning the sale of vehicles containing mercury products.

- Implement a phased strategy to reduce mercury contamination of scrap through elimination and separation measures. If, after a 3-year period, the source reduction measures do not achieve emission reduction goals, require the installation of air pollution control.
- Ensure that measures to reduce mercury contamination of scrap are developed through a cooperative process involving government agencies and affected industries, including automobile manufacturers, automobile recyclers, and those who crush, shred, or otherwise process scrap metal.
- Designate mercury switches as a Universal Waste in New Jersey.
- Require testing of carbon injection to determine its effectiveness for iron cupolas and steel furnaces. Where scrubbers are used, require testing of effectiveness and measures to improve effectiveness.
- Require periodic stack testing with the frequency depending upon the mercury emission level.
- Educate auto dismantlers, shredders, fleet managers, vehicle service facilities, and other relevant audiences about the importance of removing mercury from vehicles before they are processed into scrap.
- Determine through measurements whether scrap processing operations including shredding release significant quantities of mercury to the environment.

## **Mercury-Containing Products in General Use**

### **Identification and Description of Source**

Mercury has been and is used in a wide variety of products, and is also a contaminant in materials used in commerce, including fossil fuels and their derivatives. Commonly used consumer products that contain mercury include some types of batteries, fluorescent lamps, thermostats, switches, and other measuring and control devices. Some of the mercury used in products or inadvertently included with products and other items in commerce can escape to the environment. Such escapes can be the result of spills or breakage. For example a broken thermometer will typically result in a small quantity of elemental mercury being dispersed in the immediate environment of the breakage. Historical uses of some products, such as mercury-containing pesticides, have resulted in direct releases to the environment.

This source category addresses mercury released from products due to breakage and subsequent mercury spillage during use, and mercury released from products that break and spill mercury during disposal or during recycling. Releases from products that occur after mercury-containing items have been deposited at a disposal site, transferred to wastewater, or re-introduced to commerce as recycled items (e.g., scrap metals) are not included in this category. Such releases are included in other reports, including the reports addressing releases from municipal solid waste incineration, wastewater treatment, sludge management, landfills, broken fluorescent tubes, laboratory uses, iron and steel manufacturing, cultural uses, and others.

### **Quantity and Estimated Uncertainty**

The quantity of mercury volatilized from products in use and during the waste disposal process can be estimated from a calculation based on a series of assumptions, estimates, and physical data for mercury. This calculation is presented in detail in Appendix B.

Combining the estimates from releases during waste handling and the mid-point of estimated releases due to in-service spillage as described in Appendix B leads to an overall estimate from this source category of approximately 300 pounds per year. Because of the numerous assumptions and approximations used to derive this estimate, an uncertainty of at least  $\pm 75\%$  is assigned.

### **Sectors Affected**

All sectors using mercury-containing products, or managing such products during disposal and recycling are potentially affected.

## **Receiving Media**

The receiving medium for mercury volatilizing from products during use or disposal is the air. Much of the mercury in products winds up in landfills, where it appears to be sequestered to a large degree, based on available data. Some mercury in products may be released to water and land as well. See separate write-ups addressing releases from municipal solid waste incineration, wastewater treatment, sludge management, landfills, broken fluorescent tubes, laboratory uses, iron and steel manufacturing, cultural uses, and others.

## **Chemical Species**

The procedures described herein assume the main mercury species subject to volatilization is elemental mercury. Other species of mercury may be released to water or land or sequestered in landfills.

## **Reduction options and associated costs and impediments**

### *Household batteries*

Thanks to federal mercury content law, mercury may no longer be intentionally introduced into household batteries, except for button cell batteries, which may contain up to 25 mg. Foreign battery manufacturers appear to be following U.S. guidelines. However, older batteries still in the possession of consumers can contain 1 to 2 percent mercury. Preventing pollution from these batteries will rely on battery collection and recycling until old batteries are no longer in the waste stream.

Batteries are Universal Waste in New Jersey. This legal designation facilitates collection and recycling by large quantity generators.

## **Recommendations**

- Support legislation requiring labeling of button batteries with mercury content.
- Support legislation banning disposal of batteries in trash incinerators (source separation).
- In state purchasing contracts, require that battery vendors take back spent batteries for recycling.
- Support and encourage collection and recycling of batteries by households and small businesses (exempt from the Universal Waste Rule).

### *Electrical lighting components*

Fluorescent lamps, including linear tubes and compact fluorescent lamps, are discussed in the “Fluorescent lamps” section of this chapter.



### *Fever thermometers*

According to EPA's 1992 projections, more than 900,000 mercury fever thermometers enter New Jersey's municipal solid waste stream each year, accounting for more than 1,000 lbs. of mercury. Each mercury fever thermometer contains about one half gram of mercury. Acceptably accurate digital, non-mercury thermometers and heat-sensitive "temperature strips" are readily available. Numerous municipalities and special districts around the nation have initiated thermometer exchange programs that collect mercury thermometers for hazardous waste disposal, and distribute digital models. Several large grocery and drug store chains have voluntarily stopped selling mercury fever thermometers; a bill in the New Jersey legislature would ban their sale in the state.

### **Recommendations**

- Support legislation banning the sale of mercury fever thermometers in New Jersey.
- Fund, support, and encourage local thermometer exchange programs.
- In state purchasing contracts, specify non-mercury thermometers in applications where digital alternatives are feasible.
- Work with small and large retailers to obtain voluntary agreements to stop selling mercury thermometers and to distribute educational materials to customers.
- Provide public education about the hazards of mercury spills from broken thermometers, safe cleanup methods, and the importance of taking mercury thermometers to a household hazardous waste collection event *before* they break.
- Educate physicians about the importance of not giving mercury thermometers to patients to take home.

### *Thermostats*

The 1997 in-use inventory of mercury thermostats in the state can be estimated at approximately 2 million thermostats, accounting for 17,670 pounds of mercury (based on an average 4.1 grams per thermostat)<sup>136</sup>. Discarded thermostats (including thermostats in demolition waste) contribute more than 600 pounds of mercury to New Jersey's municipal solid waste annually.

Mercury-containing thermostats are Universal Wastes in New Jersey, a designation intended to facilitate proper (hazardous waste) disposal or mercury recycling by large quantity generators (more than 100 kg [about 220 lbs.] of hazardous waste per month). However, one may assume that most heating contractors and plumbers who install or replace thermostats are unlikely to qualify as large generators. As a number of states move towards banning sale or solid waste disposal of thermostats, Honeywell and other thermostat manufacturers initiated a multi-state take-back program, the Thermostat Recycling Corporation (TRC) in 1998. Unfortunately, the program has never been promoted effectively in New Jersey. In all of 2000, only 354

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<sup>136</sup> Northeast States and Eastern Canadian Provinces Mercury Study, A Framework for Action, February 1998.

thermostats, accounting for 2.7 lbs. of mercury, were collected at the ten New Jersey locations listed by TRC.<sup>137</sup>

Digital thermostats containing no mercury are the choice of many contractors, although mercury thermostats continue to be sold, especially to the do-it-yourself home repair market. A survey of retailers shows that mercury thermostats are often less expensive and more user-friendly than programmable electronic thermostats which do not contain mercury, although programmable thermostats may have energy conservation advantages.

The industry estimates the life of a mercury thermostat at between 30 and 40 years. Therefore, between 2 and 3 percent of all thermostats may be expected to be retired annually.

### **Recommendations**

- Propose and support legislation banning the sale of mercury-added products, including thermostats, for which acceptable non-mercury substitutes are available.
- Propose and support legislation banning mercury-containing thermostats from MSW or demolition waste disposal.
- In state purchasing and construction contracts, specify all-digital thermostats and require contractors to remove and recycle thermostats containing mercury.
- Pressure the National Electrical Manufacturers' Association (the trade group that operates TRC) to promote thermostat recycling effectively in New Jersey.
- Educate heating/air conditioning contractors and plumbers about the Universal Waste Rule and the importance of recycling thermostats containing mercury through TRC.
- In partnership with hardware stores, educate do-it-yourselfers about environmentally preferable digital thermostats and the importance of recycling mercury thermostats through household hazardous waste programs.

### *Dental uses of mercury*

See the separate section on dental office waste in this chapter.

### *Mercury light switches*

According to EPA's 1992 projections, discarded mercury-containing household switches accounted for 114 lbs. of mercury in New Jersey municipal solid waste in 2000. Like thermostats, mercury light switches (wall switches) generally enter the waste stream during remodeling or demolition of homes, offices, and commercial buildings.

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<sup>137</sup> <http://www.nema.org/government/environment/results2000.html>

In general, silent light switches contain mercury tilt switches that have between 2 and 3.5 grams of mercury. Alternatives include hard-contact switches, solid-state switches, electro-optical switches, and a number of types of sensors.

As with thermostats, control of this source depends upon effective education of building and demolition contractors.

### **Recommendations**

- Propose and support legislation banning the sale of mercury-added products, including light switches, for which acceptable non-mercury substitutes are available.
- In state demolition and construction contracts, specify non-mercury light switches. Require contractors to remove and recycle switches containing mercury.
- Educate building and demolition contractors about the importance of careful removal and proper disposal of mercury switches.
- In partnership with hardware stores, educate do-it-yourselfers about the hazards of mercury and the importance of recycling old switches and replacing them with non-mercury alternatives.

### **Research, Development, and Monitoring Options**

Monitoring of the inlet stack gas mercury concentration at all New Jersey MSW incinerators, and monitoring of the total mercury concentration in the ash at two MSW incinerators (Warren County and Essex County) should continue. The data resulting from these monitoring efforts can be used to estimate the concentration of metals in MSW to determine if levels are declining, as expected due to minimization efforts and disposal trends. Current testing protocols should be fully assessed to determine if they are comprehensive.

### **Outreach and Educational Options**

Educating the consumer on the importance of the proper post-consumer-use management of mercury-containing products is recommended. This may be done as previously mentioned through product information. However, the Department may want to consider informing and educating consumers by the use of general awareness publications and/or via the Department's web page.

## **Non-Ferrous Metals, Including Aluminum and Aluminum Scrap Processing**

### **Identification and Description of Source**

There are several facilities in New Jersey that produce non-ferrous metals including aluminum and associated products. At least two of these facilities are believed to use recycled aluminum as a feedstock and to process this material using heat. Based on the large mercury emissions from iron and steel manufacturing facilities which also process recycled metals (see separate write-up elsewhere in this document), contamination of recycled metals with mercury is suspected. Since mercury tends to preferentially amalgamate with aluminum rather than ferrous metals, mercury contamination in the recycled metals stream might tend to be associated more with aluminum than ferrous metals. Therefore, it is possible that facilities that process recycled aluminum using heat have mercury emissions.

### **Quantity and Estimated Uncertainty**

As of May 2001, no stack testing for mercury had been performed at these New Jersey facilities. Emission quantities are unknown. Emissions quantities could possibly be in approximately the same range as emissions from iron and steel manufacturers in New Jersey. An approximate estimate in the range of 1000 pounds per year is offered until data are available.

### **Sectors Affected**

The several facilities that process aluminum and suppliers of recycled aluminum could be affected.

### **Receiving Media**

The receiving medium is expected to be air.

### **Chemical Species**

Species of emissions are unknown. If mercury is released during melting of recycled aluminum, it is likely that most of it is elemental.

### **Reduction, Outreach, and Education Options and Associated Costs and Impediments**

These are unknown at this time. Practices could include education and outreach toward metal processors where separation efforts (removing mercury containing switches, etc.) would result in decreased mercury in the feedstock. Costs may include additional labor. Capture of mercury released from mercury amalgamated with aluminum would require pollution control devices. Carbon adsorption/carbon injection might be an option.

### **Research, Development, and Monitoring Options**

The USEPA has awarded a grant for a NJDEP pilot project which will include stack testing at a small number of facilities. The project will seek to assess and provide quantities of emissions, including mercury. If data collection proves successful, the results from the project will be used to refine the inventory for this source.

### **Recommendations**

- Complete pilot project testing emissions from New Jersey facilities.
- Once emissions are identified, review inventory and if appropriate, propose emission reduction options.

## Painted Surfaces

### Identification and Description of Source

Inorganic mercury compounds of very low solubility were formerly used as additives in marine coatings and paints to prevent fouling of boat hulls by bacteria and other marine organisms.. This use had largely been discontinued by the mid-70s,<sup>138</sup> with substitution of organotin compounds. Emissions from this source are believed not likely to be significant in New Jersey today since the use ended so long ago, and are not considered further in this report.

A related but different use of mercury compounds in paint was common until the early 1990s and is examined in more detail herein. This use was the addition of phenyl mercuric acetate (PMA) and similar compounds to water-based paints. These were added to prolong shelf-life by controlling bacterial fermentation in the can and to retard fungus attacks upon painted surfaces under damp and humid conditions. In July 1990, partly in response to an incident in 1989 in Michigan when a 4-year old boy suffered mercury poisoning after mercury-containing paint was applied to the interior of his home,<sup>139</sup> all registrations for mercury biocides used in paints and coatings, except for PMA, were voluntarily cancelled by the registrants. In May 1991, EPA announced the voluntary cancellation of the remaining PMA registrations which were for exterior paints and coatings.<sup>140</sup> Several studies had indicated that when mercury-containing coatings and paints were applied, the painted surfaces released elemental mercury to the air.<sup>141,142</sup>

### Quantity and Estimated Uncertainty

Large quantities of PMA and other organic mercury-containing biocides were used in the U.S. until 1990.<sup>143</sup> Apportioning the U.S. quantities to New Jersey, assuming that New Jersey accounted for about 3% of U.S. use based on population, indicates that approximately 15,000 pounds of mercury was used in paint applied in New Jersey each year from the mid-60s until 1991.

Estimating the temporal pattern of mercury releases from surfaces to which this paint was applied requires an estimate of the half-life of the mercury in the painted surface. One estimate

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<sup>138</sup>. U.S. Department of Commerce, Bureau of Mines, Various years, *Minerals Yearbook*, U.S. Government Printing Office, Washington, D.C.

<sup>139</sup>. Beusterien, Kathy, R. Etzel, M. Agocs, G. Egeland, E. Socie, M. Rouse, and B. Mortensen, 1991, Indoor air mercury concentrations following application of interior latex paint, *Arch Environ. Contam. Toxicol.* 21, 62-64.

<sup>140</sup>. USEPA, 1992, *Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000*, EPA 530-R-92-013, USEPA, Office of Solid Waste and Emergency Response, April, 1992.

<sup>141</sup>. Beusterien, et al., 1991

<sup>142</sup>. Agocs, Mary, R. Etzel, R. Parrish, D. Paschal, P. Campagna, D. Cohen, E. Kilbourne, and J. Heese, 1990, Mercury exposure from interior latex paint, *New England Journal of Medicine*, 323, 1096-1101.

<sup>143</sup>. U.S. Department of Commerce, Bureau of Mines, Various years, *Minerals Yearbook*, U.S. Government Printing Office, Washington, D.C.

is that the half-life was approximately one year.<sup>144</sup> Other estimates are in approximate agreement with this value, although it appears from some data that the half-life could have been somewhat longer.<sup>145</sup> If a half-life of approximately 1.5 years and first-order exponential degradation are assumed, a relatively steady rate of supply of a material to a system would result in a quasi-steady state after 3 or 4 years. Regardless of the half-life, with a constant input a steady-state will evolve, where inputs to the system, in this case applications of mercury in paint, equal outputs, in this case mercury emissions. The mathematical expression of this relationship is  $M_i = Mk$ , where  $M_i$  represents the mass coming into the system,  $M$  represents the reservoir of mass in the system (in this case, painted surfaces) and  $k$  represents the rate of loss per time period.  $Mk$  thus represents the emission during the period.

With a steady input of 15,000 pounds per year, the yearly emission would have also been 15,000 pounds per year once steady-state was reached. With a half-life of 1.5 years, the steady-state reservoir would have been about 33,000 pounds. Once input ceased, which in the case considered here was approximately 1991, emissions would have tapered off.

Today, emissions from painted surfaces are likely to be less than 200 pounds per year, and should fall below 20 pounds per year within several more years. Related emissions resulting from discarded painted objects and paint containers, many of which probably made their way into waste streams and were incinerated, are also likely to be very low today, and declining. However, as recently as the early 1990s, emissions from this source may have been the largest single source of air emissions of mercury in the state. Some of these emissions were likely to indoor environments. That these emissions have largely disappeared today is evidence of the value of pollution prevention, which in this case took the form of elimination of mercury-containing biocides from paint.

### **Sectors Affected**

None.

### **Receiving Media**

Air.

### **Chemical Species**

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<sup>144</sup>. Minnesota Pollution Control Agency, 1998, *Options and Strategies for Reducing Mercury Releases, Source Reduction Feasibility and Reduction Strategies Committee Report*, Minnesota Pollution Control Agency, Policy and Planning Division, Majors Air Unit, 520 Lafayette Road, St. Paul, MN 55155, October 2, 1998.

<sup>145</sup>. Agnocs, M., et al., 1990.

The primary chemical species emitted from painted surfaces is believed to be elemental, although the parent compound itself, PMA or a related substance, may be emitted as well.

### **Reduction Options and Associated Costs and Impediments**

Major reductions have already been achieved by cancellation of registration of mercury compounds used in paint and similar applications.

### **Research, Development, and Monitoring Options**

Any new biocides added to paints should be thoroughly evaluated prior to introduction.

### **Outreach and Educational Options**

No action necessary. This source is rapidly declining, and should approach zero in a few years. It is possible that some emissions may occur from old painted surfaces uncovered during renovations and re-painting operations. However, since the half-life of mercury in paint films is likely very low, and since most paint surfaces are porous to some degree, it is unlikely that significant amounts of mercury remain even in underlying paint layers.

### **Recommendations**

No action necessary.



## Crematoria

### Identification and Description of Source

New Jersey's 19 crematoria disposed of 19,135 corpses in 1997.<sup>146</sup> This represents an increase over the 14,427 cremations of 1990 and the 18,385 cremations of 1995. This increase suggests that the consistent growth in number of cremations apparent nationally (50,000 cremations in 1958; 350,000 in 1989<sup>147</sup>) is mirrored in New Jersey. Dental fillings contain mercury, and when a corpse is cremated, this mercury is vaporized. Estimates vary on the number of fillings in a typical corpse, and the average quantity of mercury in those fillings. The reported range, assuming that amalgam is 50% mercury, is from 0.8 to 5.6 grams per corpse<sup>148,149,150,151</sup> with a mean of 2.9 grams mercury per cremated corpse.

### Quantity and Estimated Uncertainty

There is some evidence that the actual emissions per cremation may be lower than the above data would suggest. One study indicated a release rate of 0.6 grams per corpse,<sup>152</sup> and another showed wide variations in amount emitted per corpse, with a mean of approximately 0.3 grams per corpse.<sup>153</sup> However, using a worst case approach, and assuming that the values noted above for quantity of amalgam per corpse are representative and that all mercury in amalgam is released upon cremation, multiplying 19,135 corpses cremated by 2.9 grams each equals about 120 pounds emitted from this source. The estimated uncertainty is high; at least 50%.

### Sectors Affected

Funeral directors and associated businesses, especially the 19 crematories, would be affected by control measures. It is possible that efforts to reduce mercury emissions from crematoria will be opposed both by crematoria operators (because such measures could increase expenses and could conceivably discourage people from choosing cremation) and by dentists (who largely still favor

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<sup>146</sup>. Dempsey, Pat, 1999, New Jersey State Funeral Directors Association, Manasquan, New Jersey, personal communication, June 17, 1999.

<sup>147</sup>. Leary, Warren, 1991, Even death a problem of pollution, *Trenton Times*, November 14, 1991.

<sup>148</sup>. Mills, A., 1990, Mercury and crematorium chimneys, *Nature* 346, 615.

<sup>149</sup>. Basu, M., and H. Wilson, 1991, Mercury risk from teeth, *Nature* 349, 109.

<sup>150</sup>. Skare, I., 1995, Mass balance and systemic uptake of mercury released from dental amalgam fillings, *Water, Air & Soil Poll.*, 80, 59-67.

<sup>151</sup>. Kunzler, P., and M. Andree, More mercury from crematoria, *Nature* 349, 746-747.

<sup>152</sup> Obenauf, P. and S. Skavronneck, 1997, *Mercury Source Sector Assessment for the Greater Milwaukee Area*, prepared for the Pollution Prevention Partnership and Milwaukee Metropolitan Sewerage District, September, 1997.

<sup>153</sup> Midwest Research Institute, 1999, *Emission Test Evaluation of a Crematory at Woodlawn Cemetery in the Bronx, NY, Final Test Report, Vol. 1*, prepared for USEPA, Office of Air Quality Planning and Standard Emission Measurement Center, 4930 Old Page Rd., Research Triangle Park, NC 27709, Attn. Foston Curtis, September 30, 1999. Mean value of results presented is 0.16 g/hr., and report states that cremations take two hours.

use of mercury amalgams). A Funeral Directors Association representative reacted negatively to the suggestion that removal of fillings be required, stating that this would likely be offensive to relatives of the deceased and would interfere with the funeral process. Discussion of a variety of policy options to reduce crematoria emissions might encourage cooperation from both dentists and crematoria operators.

### **Receiving Medium**

Air is the receiving medium.

### **Chemical Species**

The mercury molecular species emitted are unknown. Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species such as  $\text{HgCl}_2$ , and species bound to particles are present.

### **Reduction, Research, Monitoring, Outreach/education Options, and Associated Costs and Impediments**

In the long term, reduced use of mercury amalgams in dentistry will result in reduced emissions from crematoria, and will have the additional benefit of reducing mercury in dental wastewater, and reducing occupational exposures of dental workers. Alternatives to mercury amalgams are available and are becoming increasingly acceptable to dentists.

There has been a great deal of public attention on the potential (controversial) health risks of mercury amalgams. But there has been essentially no public education about the much more certain environmental impact of dental amalgams. While cremation may be an uncomfortable topic of discussion for some people, most people can nevertheless understand that if they have mercury amalgams in their teeth, that mercury is eventually going to end up in the environment. A sensitive, carefully thought out public education effort could encourage both dentists and patients to consider the environmental implications of the choice of mercury versus non-mercury dental amalgams.

In June 2000, the Dental Board of California ruled that dentists there must warn patients that silver (mercury) fillings will expose them to mercury, a metal on the state's list of hazardous substances. A similar type of warning could tell patients that use of mercury amalgams results in long-term emissions of mercury to the environment.

Some people who now have mercury amalgams might wish to take steps to ensure that their mercury fillings are not emitted into the atmosphere after they die. Living wills and organ donor programs could include options which would allow people to specify removal of mercury fillings prior to cremation.

Mercury emissions from crematoria could be controlled by the same technologies used for municipal waste incinerators and medical waste incinerators, such as carbon injection. The removal of mercury amalgams from corpses prior to cremation may be less expensive than installing pollution control equipment on crematoria.

Although this source represents a relatively small portion of the overall estimated air emissions in New Jersey, it has the potential to grow in magnitude. However, the expected increase in number of cremations may partially be offset by the reduced number of amalgams in Americans born after 1950 when fluoride use increased. Emissions from this source should be tracked and the estimated emissions quantity regularly updated.

### **Recommendations**

- Encourage voluntary removal of amalgams from corpses, such as through living wills.
- Public education to encourage patients to consider the environmental implications of the choice of mercury versus non-mercury dental amalgams.
- Continue to track emissions inventory.
- Stack controls on crematoria.

## Dental Office Waste

### Identification and Description of Source

Mercury amalgam is used for dental fillings. Mercury-containing waste is generated from the creation of fillings and from the removal or replacement of fillings. The mercury in the fillings may be eventually released into the environment at the end of the patient's life; that amalgam pathway is discussed in the assessment of emissions from crematoria.

### Quantity and Estimated Uncertainty

As of May 2001, there were 7,506 active dentists in New Jersey.<sup>154</sup> Review of data summarizing tests of wastewater leaving dental office buildings in six U.S. cities and one European city suggest that the mean discharge may be in the range of 0.1 g/dentist/day,<sup>155</sup> although the wide variation in methods and results of these studies suggest that this mean value should be considered very approximate.<sup>156</sup> This mean value is consistent with a Massachusetts study, which estimated that dental facilities discharge in wastewater from 0.06 g to 0.34 g mercury per facility per day.<sup>157</sup> Assuming that perhaps 10% of the dentists active in New Jersey do not routinely fill teeth, there are about 6800 dentists that might discharge in the range of 0.1 g mercury per day. This indicates that the contribution of dental amalgam to the wastewater flow from dental offices in New Jersey could be on the order of 450 lbs. per year, plus or minus at least 300 lbs./yr.

The chairside traps typically present in dental offices collect the larger particles of amalgam. These traps are reported to collect in the range of 60% to 70% of the total mercury waste.<sup>158,159</sup> Additional filter systems, such as vacuum filters or air/water separators present in many offices, will collect additional, smaller amalgam particles.<sup>160</sup> Assuming that about 30% goes down the

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<sup>154</sup> NJ Department of Law & Public Safety (NJDLPS), 2001, from Melissa Roberts, NJDLPS, Division of Consumer Affairs, Bureau of Centralized Licensing, Trenton, NJ, May 14, 2001.

<sup>155</sup> Johnson, Bill, 1999; Mercury source identification update: dental offices and human waste, technical memorandum from Bill Johnson, EIP Associates, to Kelly Moran, Palo Alto Regional Water Quality Plant, Palo Alto, CA 94303. This memo reports the following estimated loads (grams/day/dentist) from dental offices; San Francisco, 0.035; Cleveland, 0.042; Seattle, 0.064; Boulder, 0.10; Boston, 0.043-0.27; Duluth, 0.1-0.3; Aarhus, Denmark, 0.25. The mean of these values is 0.121 g/dentist/day, with a 95% confidence interval of 0.044 to 0.198 g/dentist/day. Assuming 6800 NJ dentists use amalgam and operate 250 days per year, this translates to a mean of 451 lbs/yr, with a lower bound of 164 lbs./yr. and an upper bound of 737 lbs./yr., or approximately 450 ± 300 lbs./yr.

<sup>156</sup> Johnson, Bill, personal communication, June, 2001.

<sup>157</sup> Massachusetts Water Resources Authority (MWRA), 1997, Mercury in Dental Facilities, MWRA, Sewerage Division, Toxic Reduction and Control Department.

<sup>158</sup> Monroe County, NY, Department of Health. 1999. Use Best Management Practices for Amalgam Handling and Recycling. Available on the web as Appendix M in Promoting a Healthier Environment: Reducing Mercury Use in Health Care, <http://www.epa.gov/glnpo/bnsdocs/merchealth/aboutmerhealth.html>.

<sup>159</sup> EIP Associates, Mercury Amalgam Treatment Technologies for Dental Offices, technical memorandum prepared for Palo Alto Regional Water Quality Control Plant, July 10, 2000.

<sup>160</sup> Johnson, William and Teresa Pichay, 2001, Dentistry, Amalgam, and Pollution Prevention, CDA Journal, 29, 509-517.

drain, and that that quantity is about 450 lbs. per year, as estimated above, the amount collected in traps would be roughly 1050 pounds per year in New Jersey.<sup>161</sup> In New Jersey, this material is typically disposed in normal municipal waste or recycled. There is uncertainty associated with these numbers and the quantity could be higher. One study reported that, prior to any filtration or trapping, dentists discharge an average of 2 g mercury per day per dentist.<sup>162</sup> Other studies reported on the amount of mercury in dentists' wastewater passing through chairside traps. If these are the only filter used, the amount could be 0.8 grams per dentist per day;<sup>163</sup> and if chairside traps and vacuum filters both are used, the amount could be 0.4 grams per dentist per day.<sup>164</sup>

Quantities of mercury amalgam particles leaving dental offices in wastewater appear to vary widely; much of the variation may be due to factors within the plumbing system, such as low points, ridges, crevices, and traps that can collect small particles.<sup>165</sup> Compared to elemental and ionic forms of mercury, mercury bound within amalgam particles may be less available for conversion to ecologically harmful methylmercury.<sup>166</sup> However, it is possible that under certain conditions more available forms of mercury may be released from amalgam particles. Ultimately, most mercury in wastewater can be expected to reach wastewater treatment facilities or be discharged to septic systems. Quantities of mercury in wastewater, sludge, and emissions from solid waste incinerators and landfills are discussed in separate write-ups elsewhere in this document.

The amount of mercury that has been used in dentistry has been reported for many years.<sup>167</sup> These data can be apportioned to New Jersey based on population. Also, with the assumption that dental amalgam has a half-life of approximately 15 years in teeth, an estimated inventory in the New Jersey population can be developed. See Figures 1 and 2.

### **Sectors Affected**

Dentists, their patients, and companies that supply materials to dentists and that provide services, including metals recycling, could be affected by efforts to reduce emissions from this sector. Insurance companies that do not currently pay the full costs of alternative restorations may also be affected.

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<sup>161</sup> An estimated mass balance for dental-related mercury wastes in Canada suggested that about 4100 pounds of mercury was discarded per year from dentists' offices, and that about 1500 pounds of this went to the wastewater stream. Since Canada's population is about four times New Jersey's, these quantities are in very close agreement with the New Jersey numbers.

<sup>162</sup> Drummond, J., Caila, M., et. al., 1995, Dental Waste Water: Quantification of Constituent Fractions, Academy of Dental Materials, Abstract P-22.

<sup>163</sup> EIP Associates, 2000, Mercury Amalgam Treatment Technologies for Dental Offices, technical memorandum prepared for Palo Alto Regional Water Quality Control Plant, July 10, 2000.

<sup>164</sup> Water Environment Federation, 1999, Controlling Dental Facility Discharges in Wastewater, Water Environment Federation.

<sup>165</sup> Johnson and Pichay, 2001.

<sup>166</sup> Johnson and Pichay, 2001.

<sup>167</sup> Minerals Yearbooks, various issues, U.S. Bureau of Mines and USGS, see <http://minerals.usgs.gov/minerals/pubs/commodity/myb/>

## **Receiving Media**

Amalgam particles that are rinsed down drains or that escape poorly maintained chair-side traps and vacuum pump filters travel through the sewer system to the wastewater treatment plant. The material collected in traps and filters is typically disposed in ordinary municipal waste. Mercury amalgam may also be discarded on occasion with regulated medical waste, in which case the mercury could be incinerated in a medical waste incinerator. Extracted teeth, including any contained amalgam, are regularly discarded as medical waste.

## **Chemical Species**

Dental amalgam is a mixture of elemental mercury with silver, tin, and copper. Mercury makes up about 40 to 50 percent of the amalgam compound.

## **Reduction Options and Associated Costs and Impediments**

### *Source Reduction Options*

Alternate, non-mercury fillings are available, and they are increasingly acceptable to dentists and patients. Many of the alternative fillings, which are composites that can be combinations of porcelain, zirconia, quartz, glass and plastic, are considered superior to mercury amalgam fillings for many applications. Not only are composite fillings tooth-colored rather than silver, they may also require smaller holes to be drilled to fill the cavity.

Nevertheless, adoption of non-mercury composite fillings has been slow. Some dentists still favor mercury amalgams because they are cheaper, easier to use, and they are confident that they are more durable. One dentist said that mercury fillings are still indicated for large fillings in back teeth where high durability is needed. Recently, however, many dentists appear to be moving away from mercury amalgam fillings and shifting to tooth-colored materials. One dentist supplied data that indicates that the percentage of restorations completed by his office that were mercury amalgam declined from 49% in mid-1997 to 20% in early 2000, and then to 12% by mid-2000. He stated that he has now become convinced that some non-mercury composite materials are superior to mercury amalgam, in part because they bond to the tooth and strengthen it. He also said he believes that use of amalgam by many dentists is only 10% of what it was a decade or two ago.<sup>168</sup> National mercury use data support the conclusion that less mercury is being used in dentistry. Figure 2 shows USGS data indicating that the quantity of mercury used in dentistry has declined by perhaps a factor of 3 since 1970.

However, some mercury use continues. It is reported that composite fillings can cost one-and-a-half to two times more than mercury amalgams, because the materials are more expensive and require more time to install. Further, it has been reported that most insurance companies do not cover the cost difference for non-mercury fillings in posterior teeth, or may not pay for a non-amalgam filling at all.

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<sup>168</sup> Weiner, Robert, DMD, Personal communication.

Concerns over patient exposure to mercury amalgams may increase the pressure to phase out mercury amalgams. For example, the Dental Board of California, on June 30, 2000, advised dentists that they should discuss with their patients the different restorative materials, and warn patients that mercury fillings will expose them to mercury, a metal on the state's list of hazardous substances. In some countries, Sweden, Germany and Canada, dental societies have recommended against using mercury fillings in certain patients, such as pregnant women, people with kidney disease and children under age 6.

Concerns over mercury emissions from crematoria and medical waste incineration, due to mercury amalgams, may also increase the pressure to eliminate the use of mercury amalgam.

In order to remove obstacles to the reduced use of mercury amalgams, insurance companies should be required to cover both mercury amalgams and non-mercury composites. Additional measures to advance the phase-out of mercury amalgams should be considered. The Task Force recommends a goal of the phase-out of mercury-containing amalgam fillings within ten years and recommends that additional efforts be made to develop alternatives to mercury amalgam.

### *Control Options*

The management of mercury-bearing dental office waste is essentially unregulated in New Jersey. But outside of New Jersey, a number of states and localities have taken measures to reduce mercury amalgam waste.<sup>169,170</sup> Massachusetts, Oregon, Minnesota, Michigan, Maine, Vermont, Seattle, Long Island, and San Francisco are among the states and localities that have developed dental amalgam waste management programs or regulations; as of June 2000, Pennsylvania is developing a program.<sup>171,172</sup> Minnesota's program is reported to have reduced the release of mercury amalgam in dental office wastewater by more than a factor of three.

As a first step, the basic guidelines for mercury amalgam waste management that have been adopted elsewhere in the country should be adopted in New Jersey as well. Manuals on best management practices for amalgam handling and recycling have been developed by a number of organizations. The recommendations from the Monroe County (New York) Department of Health are reprinted below.

Best Management Practices for Amalgam Handling and Recycling  
(Monroe County, New York, Dept. of Health, 1999)

#### *Amalgam Storage and Handling:*

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<sup>169</sup> Hughes, J., and Ingram, B. J., 1995, The Concern Over Mercury and Wastewater. *J. Michigan Dental Assoc.* April/May 1995.

<sup>170</sup> Western Lake Superior Sanitary District WLSSD, 1994. A Guide for Dentists: How to Manage Waste from Your Dental Practice, from Blueprint for Mercury Elimination, WLSSD, 2626 Courtland St., Duluth, MN, 218-722-0761.

<sup>171</sup> Oregon Dental Association 1998. The Environmentally Responsible Dental Office: The Oregon Dentist's Guide to Best Management Practices of Dental Waste.

<sup>172</sup> Massachusetts Water Resources Authority, 1998. Dentistry and the Environment.

Stock your amalgam materials in a good choice of capsule sizes, in order to better select the right amount of material for a particular restoration. This will minimize waste.

Dental scrap amalgam should be collected and stored in two designated, tightly closed, widemouth plastic containers. One container should be labeled CONTACT AMALGAM (amalgam that has been in the patient's mouth). The other should be labeled NONCONTACT AMALGAM.

Most recyclers prefer that contact amalgam be transported for recycling in a disinfectant. The liquid is visual evidence that the contact amalgam has been disinfected. Noncontact amalgam in a tightly sealed container can be stored and transported dry.

#### *Amalgam Capsule Handling:*

Collect and store the entire contents of broken or unusable capsules with your noncontact scrap amalgam. If empty dental amalgam capsules contain no visible amalgam materials, they may be placed in the trash.

If there is a spill of mercury from a capsule, contain it and clean it up immediately. Keep mercury clean-up materials on hand, and train a staff member in proper spill clean-up. Inexpensive mercury clean-up materials are available from science and safety equipment suppliers.

#### *Amalgam Trap and Filter Handling:*

When the fine particles of amalgam come in contact with cleaning agents and chemicals in the suction system and sewers, the mercury may be released. Large particles of amalgam can be prevented from entering the sewer system by the use of chair-side traps and vacuum pump filters. Material captured in the traps and filters can be sent to a recycler. Calculations based on data in scientific literature indicated that, when used properly, chair-side traps and vacuum pump filters can capture about 70% of the amalgam that enters the vacuum system.

- Never rinse scrap amalgam down the drain.
- Never place scrap amalgam in the medical waste red bag.
- Never place scrap amalgam in the trash.

Recommended techniques for collecting amalgam from the chair-side traps are as follows:

1. Change or clean chair-side amalgam traps often. The frequency may vary from daily to weekly depending on how often the chair is used for amalgam placement or removal and the effectiveness of the suction.
2. Flush the vacuum system with disinfecting line solution before changing the chair-side trap. The best method is to flush the line at the end of the day, and then change the trap the first thing the next morning.
3. Use universal precautions (gloves, glasses and mask) when handling the chair-side trap. Choose utility gloves intended for cleaning and handling wastes for this procedure.
4. Do not place gloves, plastic bags or paper towels into the recycling container. These add to the volume of the waste created and cause problems in the recycling equipment.
5. Remove all visible amalgam by tapping the contents into the container labeled CONTACT AMALGAM. Close the cover tightly. If the trap is visually clean, it can be put in the trash. These visually clean traps have been determined to be nonhazardous (shown by Toxicity Characteristic Leaching Procedure (TCLP) to be acceptable for landfilling). A heavily



contaminated trap should always be recycled. It should be placed in the contact amalgam container.

Vacuum pump filters are usually located upstream of the central vacuum pump. Recommended techniques for recycling the vacuum pump filters are as follows:

1. Replace or dispose of these filters regularly as recommended by the equipment manufacturer.
2. Use universal precautions.
3. Remove the filter and decant, over a tray, as much liquid as possible without losing visible amalgam.
4. Put the lid on the filter and place the filter in the box in which it was originally shipped. When the box is full, the filters should be recycled.

#### *Plumbing Replacement and Repairs*

After your office adopts its new amalgam management practices, it may be a good time to replace sink traps. Mercury from past practices often settles at low points such as sink traps and sump. The slow dissolution of the mercury in a sink trap or sump can release mercury into the wastewater for years after past disposal practices have been corrected. Whenever these plumbing parts are moved or cleaned, caution should be taken to avoid spilling the contents in case amalgam or mercury are present. Pour and brush out the sludge and handle it as you would handle contact amalgam. The plumbing parts can be put back in place or discarded in the trash.

#### *Renovations:*

If you have an older dental office, alert renovators to the possibility of mercury contamination in carpets, in floor cracks, behind moldings and other areas where bulk mercury may have been used, or where amalgam capsules may have been spilled. Call your county health department if you have questions about disposal of renovation debris.

#### *Keep Informed on Separator Technologies:*

Systems are available to treat wastewater contaminated with amalgam particles that are too fine to be caught in traps or filters. Most systems employ centrifugation or enhance sedimentation of particles. Some can also capture mercury that is in solution. Some of the new equipment can remove more than 99% of the mercury in the wastewater. It is used in some European countries, where removal rates of at least 95% are required. The systems are being evaluated in dental offices in the US. Equipment can be purchased or leased.

#### *Recycle Bulk Elemental Mercury Stock:*

In 1994 the American Dental Association recommended that dentists eliminate the use of bulk dental mercury by switching to precapsulated amalgam alloy in their practices. Measurement of the ratio of liquid mercury to amalgam powder is much more exact with the precapsulated technique. There is also less possibility of leakage during trituration. The use of precapsulated amalgam alloy eliminates mercury dispensers and containers as sources of mercury vapor, and eliminates the possibility of spillage of a large quantity of mercury.

Recycle Bulk Mercury. If there is a spill of a large amount of bulk mercury before it is eliminated from your office, call your county health department.

- Recycle any bulk mercury that may still be on hand in your office.

A list of locations to which amalgam waste can be sent for recycling in New Jersey needs to be developed. However, recycling is not an ultimate solution, since mercury may ultimately enter another source sector.

These basic guidelines do not suggest the installation of new equipment to remove mercury amalgam from dental wastewater. They primarily explain the procedures for mercury management and for recycling, rather than throwing away, the mercury amalgam that is collected by standard traps and filters.

Systems are available to treat wastewater contaminated with amalgam particles that are too fine to be caught in traps or filters.<sup>173</sup> Most systems employ centrifugation or enhance sedimentation of particles. Some can also capture mercury that is in solution. Some of the new equipment can remove more than 99% of the mercury in the wastewater. These systems are used in Germany and in Sweden, which require removal rates of at 95% and 90%, respectively, of the "chairside" mass loading. Such systems are reported to be required in dental offices in several US municipalities.

### **Research, Development, and Monitoring Options**

The existing dental waste management programs only include the recycling of the large particles of amalgam trapped in standard dental office filters, and recycling of any leftover amalgam. The standard dental office filters do not trap small particles or mercury in solution. The potential use of more effective systems, such as those already required in Sweden, Germany, and elsewhere should be considered.

Reasons for the current cost differential between mercury-containing amalgam and alternate materials (e.g., materials, labor, etc.) should be determined.

### **Outreach and Educational Options**

Dental associations in the U.S., unlike associations in some other countries, have been resistant to phasing out mercury. Outreach to dentists and dental societies to clarify the reasons for switching to alternatives is important. Public education will encourage consumers to select non-mercury restorations.

New Jersey dentists and the New Jersey Dental Association are largely unaware of the need to collect and recycle mercury amalgam wastes. DEP should work with the New Jersey Dental Association and local and regional mercury recyclers to adopt guidelines for management of mercury waste that are at least as stringent as those that have already been implemented elsewhere in the United States.

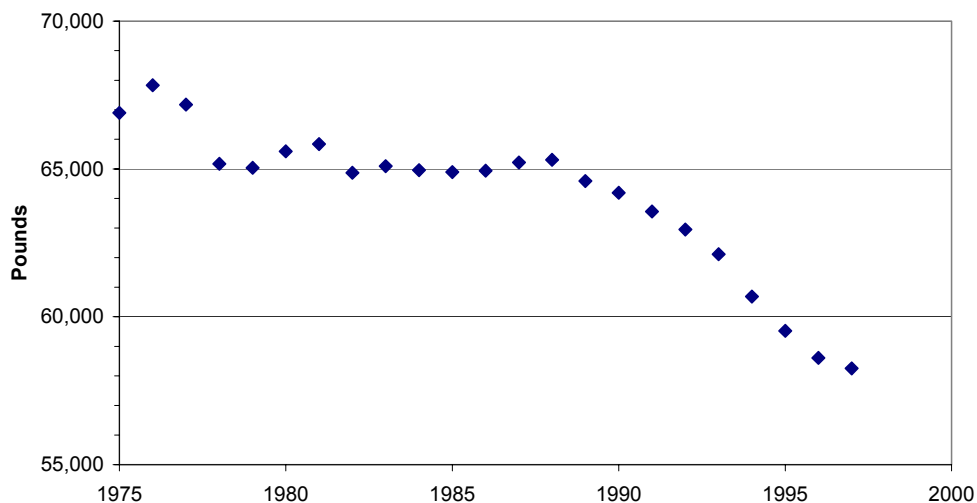
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<sup>173</sup> Fan, P. L. et al., 1997, Environmental Issues in Dentistry - Mercury. *International Dental Journal*, 47:105-109.

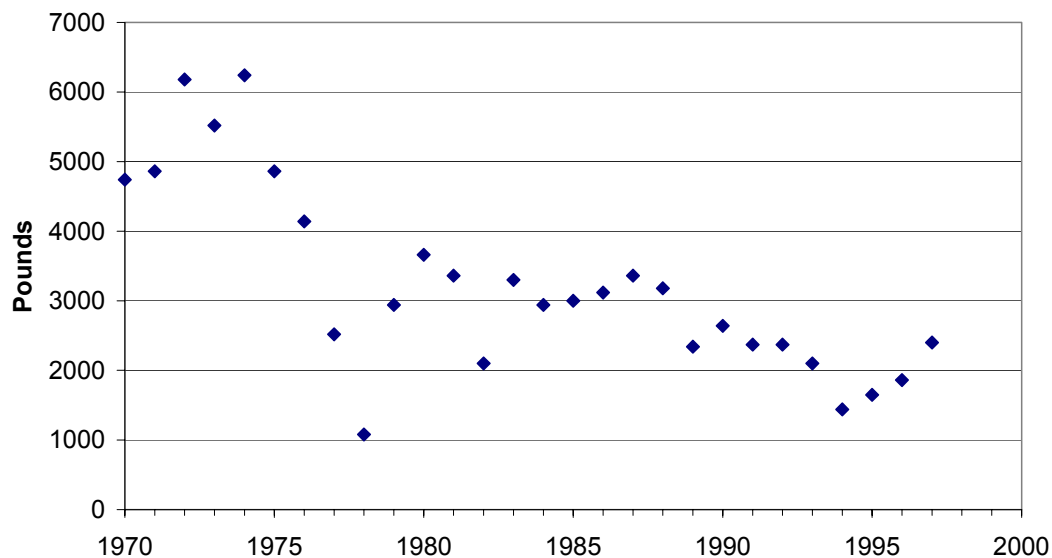
## **Recommendations**

- Adopt in New Jersey effective guidelines for mercury amalgam waste management that have been adopted elsewhere in the country.
- Reduce the use of mercury-containing amalgam through a public education/awareness program encouraging selection of alternatives.
- Phase out the use of mercury-containing amalgam for dental fillings.
- Require insurance companies to cover the cost of non-mercury restorations.
- In New Jersey, follow the California model of requiring dentists to explain the properties of mercury and the relative costs and benefits of mercury vs. non-mercury restorations.

**Figure 1**  
**Mercury in amalgam;**  
**estimated inventory in NJ population**  
 from U.S. Bureau of Mines and USGS data, apportioned to NJ  
 assuming 15-year half-life for mercury in tooth fillings



**Figure 2**  
**Mercury used in dentistry, NJ**  
 from U.S. Bureau of Mines and USGS data, apportioned to NJ



## **Laboratories**

### **Identification and Description of Source**

Mercury is used in laboratories in instruments, reagents, preservatives, and catalysts. Some of this mercury could be released in laboratory wastewater or solid waste streams. Such quantities will be included within other write-ups discussing wastewater and solid waste management facilities, including landfills and incinerators. Some mercury is emitted directly to the atmosphere.

### **Quantity and Estimated Uncertainty**

In 1994, in the U.S., an estimated 1.1 tons of mercury were emitted into the atmosphere from general laboratory use.<sup>174</sup> Apportioning this quantity to New Jersey, based on population, suggests that approximately 70 pounds of mercury per year are released. The relatively high density of research facilities in New Jersey suggests that this quantity should be adjusted upward by perhaps 25%. An emission of approximately 90 pounds per year from this source is assumed.<sup>175</sup>

### **Sectors Affected**

Laboratories, which are primarily associated with the industrial and commercial sectors, including health care facilities and educational institutions, could be affected by measures to reduce emissions from this source.

### **Receiving Media**

Emissions to the air, expected to be primarily through lab vents, are included in this source. Possible laboratory emissions to water and solid waste are included in the total estimates for these sources, discussed in other write-ups in this document.

### **Chemical Species**

Species emitted are expected to be primarily inorganic mercury species, including elemental mercury. Pharmaceutical companies use and may release various organic species such as Thimerosal.

### **Reduction Options and Associated Costs and Impediments**

Carbon adsorption filters could be used on affected lab hoods as necessary, with added costs.

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<sup>174</sup> USEPA, 1997, *Mercury Study Report to Congress, Volume II: An Inventory of Anthropogenic Mercury Emissions in the United States*, EPA-452/R-97-004, December, 1997.

<sup>175</sup>  $1.1 \text{ ton}/250 \text{ million US population} \times 8 \text{ million New Jersey population} \times 2000 \text{ lb./ton} \times 1.25 \approx 100 \text{ lb. mercury}$  emission from general lab use per year in New Jersey.

### **Research, Development, and Monitoring Options**

Better data on actual emissions from this source are desirable.

### **Outreach and Educational Options**

Outreach and education efforts offer the opportunity of reducing use and estimated releases. Such efforts could be targeted to scientific and research organizations.

### **Recommendations**

- Require carbon adsorption filters in laboratory hoods.
- Acquire better data on quantities of release.
- Reach out to scientific and research organizations to encourage the use of practices that reduce emissions.
- Laboratories should document purchases and spills of mercury and mercury compounds.
- Alternatives to mercury and mercury compounds should be encouraged.

## **Medical Waste Incineration**

### **Identification and Description of Source**

Medical waste, which includes infectious (red bag) and non-infectious waste from medical and veterinary offices, clinics, and hospitals, is incinerated at 11 facilities in New Jersey, including hospitals and research facilities.

### **Quantity and Estimated Uncertainty**

Stack tests carried out pursuant to NJDEP permits indicate that the total emissions from these facilities are very low, in the range of 2 pounds per year.

### **Sectors Affected**

The facilities that incinerate the waste would be affected by efforts targeting this sector.

### **Receiving Media**

The emissions are to the air.

### **Chemical Species**

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as  $\text{HgCl}_2$ , and species bound to particles are present.

### **Reduction Options and Associated Costs and Impediments**

Pollution prevention measures, including source reduction, re-use, recycling, and separation prior to incineration could all be effective. These practices are currently being employed to a large degree, and this is a major reason emissions from this sector are so low in New Jersey. Mercury sources in medical waste include batteries, fluorescent lamps, thermometers, plastic pigments, antiseptics, diuretics, infectious waste bag pigments and CAT scan paper.

New Jersey should adopt the New England Governors/Eastern Canadian Premiers<sup>176</sup> recommended emission limit for medical waste incinerators. All New Jersey medical waste incinerators already have achieved this level with pollution prevention measures. Adopting a limit will prevent backsliding and help provide an example to other jurisdictions.

Many previous sources have been closed due to more stringent air emission standards. The federal government has set a goal of reducing air emissions of mercury from this source by 90% by the year 2005.

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<sup>176</sup> New England Governors/Eastern Canadian Premiers Mercury Action Plan, 1998, <http://www.tiac.net/users/negc/1998mercuryplan.html>, June 1998.

**Research, Development, and Monitoring Options**  
**Outreach and Educational Options/Recommendations**

None recommended due to the low quantity of the source in New Jersey.



## Medical Waste, Not Incinerated

### Identification and Description of Source

Mercury-containing items from this source category result from the disposal of waste that is generated by the healthcare industry. Mercury can be found in both biomedical and normal solid waste streams produced by medical facilities as described below.

A study was commissioned by the Florida Department of Environmental Protection to evaluate the use of mercury in Florida's medical facilities<sup>203</sup>. This study concluded that the medical industry in Florida uses mercury in the following products or devices:

- Thermometers
- Sphygmomanometers
- Medical tubes
- Switches
- Barometers
- Manometers
- Gauges
- Mercury-containing lamps
- Batteries
- Plastics (mercury in plastic pigments)
- Laboratory products and reagents
- Veterinary products
- Vaccines and pharmaceuticals
- Dental amalgam

A listing of more specific sources of mercury can be found in Appendix B of the Florida report. For example, under the general category of laboratories, Appendix B lists six mercuric chloride-based fixatives, thirteen mercury-containing reagents and seven stains that contain mercury compounds. The Task Force expects that the medical facilities in New Jersey utilize similar products in their operations.

In general, wastes produced by medical facilities take four forms: biomedical waste, hazardous waste, solid waste and low-level radioactive waste. Low-level radioactive waste disposal is not an issue associated with mercury in New Jersey. Potential mercury releases associated with solid waste and hazardous waste are discussed elsewhere in this document.

Biomedical waste is referred to as Regulated Medical Waste (RMW) in New Jersey and is regulated by the New Jersey Solid Waste Regulations, Subchapter 3A. These regulations define RMW as:

“...any solid waste, generated in the diagnosis, treatment (for example, provision of medical services), or immunization of human beings or animals, in research pertaining thereto, or in the

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<sup>203</sup> Florida Center of Solid and Hazardous Waste Management, Mercury in Florida's Medical Facilities: Issues and Alternatives. Report #S-97-15, December 1997.

production or testing of biologicals, that is not excluded or exempted under (b) below, and that is listed or meets any waste characteristic classification criteria described in the following table:

**TABLE  
REGULATED MEDICAL WASTE**

	<b>Waste Class</b>	<b>Description</b>
1.	<b>Cultures and Stocks</b>	Cultures and stocks of infectious agents and associated biologicals, including: cultures from medical and pathological laboratories; cultures and stocks of infectious agents from research and industrial laboratories; wastes from the production of biologicals; discarded live and attenuated vaccines; and culture dishes and devices used to transfer, inoculate, and mix cultures.
2.	<b>Pathological Wastes</b>	Human pathological wastes, including tissues, organs, and body parts and body fluids that are removed during surgery or autopsy, or other medical procedures, and specimens of body fluids and their containers.
3.	<b>Human Blood and Blood Products</b>	Liquid waste human blood; blood; items saturated and/or dripping with human blood; or items that were saturated and/or dripping with human blood that are now caked with dried human blood; including serum, plasma, and other blood components, and their containers, which were used or intended for use in either patient care, testing and laboratory analysis or the development of pharmaceuticals. Intravenous bags, soft plastic pipettes and plastic blood vials are also included in this category.
4.	<b>Sharps</b>	Sharps that were used in animal or human patient care of treatment or in medical research, or industrial laboratories, including sharp, or potentially sharp if broken, items such as, but not limited to, hypodermic needles, all syringes to which a needle can be attached (with or without the attached needle) and their components, including those from manufacturing research, manufacturing and marketing, pasteur pipettes, scalpel blades, blood vials, carpules, needles with attached tubing, and culture dishes (regardless of presence of infectious agents). Also included are other types of broken or unbroken glassware that were in contact with infectious agents, such as used slides and cover slips.
5.	<b>Animal Waste</b>	Contaminated animal carcasses, body parts, and bedding of animals that were known to have been exposed to infectious agents during research (including research in veterinary hospitals), production of biologicals, or testing of pharmaceuticals.
6.	<b>Isolation Wastes</b>	Biological waste and discarded materials contaminated with blood, excretion, exudates, or secretions from humans who are isolated to protect others from certain highly communicable diseases, or isolated animals known to be infected with highly communicable diseases.
7.	<b>Unused Sharps</b>	The following unused, discarded sharps, that were intended to be used: hypodermic needles, suture needles, syringes, and scalpel blades.”

Exclusions from the preceding definition can be found in the New Jersey Administrative Code at N.J.A.C. 7:26-3A-6.

Due to the nature of the operations conducted in medical facilities, mixing of the different types of wastes can occur. Items that are broadly contaminated with regulated body fluids (human or animal) must be segregated and handled as medical waste in New Jersey if the items are not cleaned for reuse. More importantly, those mercury-containing items that are disposed of are combined with mercury-free waste as “red bag” waste. Because of the potential infectious nature of red bag waste, the opportunity for source separation and/or recycling of these mercury-containing items is lost once the wastes are mixed.

The disposal method for waste produced by medical facilities is dictated by the type of waste produced. Solid waste can be discarded with regular wastes via the municipal waste disposal system. Regulated medical waste disposed of within New Jersey must be sent to a registered intermediate handler/destination facility along with a mandatory New Jersey medical waste tracking form. Regulated medical waste may be transported only by transporters registered with

the State of New Jersey. Medical waste disposed of out-of-state is required to be shipped with a medical waste tracking form as well. Generators are required to verify that out-of-state medical waste disposal facilities are authorized to accept such wastes by the receiving state.

Regulated medical waste is disposed of and/or treated by various methods. Medical waste is considered “destroyed” in New Jersey when it is no longer generally recognizable as medical waste because all components of the waste have been ruined, torn apart, or mutilated to produce unrecognizable and unusable pieces smaller than three quarters of an inch (sharps must be less than one half inch). Medical waste “treatment” is defined as a change in the biological character or composition of regulated medical waste to reduce or eliminate its potential for causing diseases through such methods, techniques or processes as incineration, steam sterilization, chemical disinfection, irradiation, thermal inactivation or any other effective method approved by the State Department of Health.

Some of the various methods used to treat medical waste are:

- Incineration - is the thermal destruction of waste for the purpose of treatment, destruction and volume reduction of the regulated medical waste. Incinerators must be permitted by the NJDEP for this purpose.
- Sewer disposal - is the direct disposal of liquid regulated medical waste into the municipal sewer system for the purpose of treatment and destruction of liquid waste.
- Steam sterilization - is the thermal treatment of regulated medical waste using steam, sometimes generated within the waste through the use of microwave or radio frequency radiation. Steam sterilization alone does not normally destroy the waste.
- Chemical treatment - is the use of a chemical such as sodium hypochlorite to treat the regulated medical waste. Chemical treatment alone does not normally destroy the waste.
- Irradiation - is the use of ionizing radiation to destroy infectious organisms in the regulated medical waste. Irradiation alone does not normally destroy the waste.
- Thermal inactivation - is the use of high temperatures to destroy infectious organisms in the regulated medical waste. Thermal deactivation alone does not normally destroy the waste.
- Disposal of RMW in a sanitary landfill - is the direct disposal of regulated medical waste in sanitary landfills. In New Jersey, only treated RMW is authorized for disposal at specially-permitted landfills for RMW.

On June 24, 1998, the American Hospital Association (AHA) and the U.S. Environmental Protection Agency (EPA) signed a “Memorandum of Understanding” (MOU) that calls for reducing hospital waste by 50% by the year 2010.<sup>177</sup> This MOU also sets the goal of eliminating

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<sup>177</sup> American Hospital Association. U.S. Environmental Protection Agency and AHA Enter Partnership to Reduce Hospital Waste. Press Release, June 24, 1998.

mercury from the hospital waste stream by the year 2005. Under this MOU, the AHA and EPA have agreed to the following:

1. Undertake collection of baseline data on hospitals' pollution prevention efforts;
2. Monitor hospitals' success in meeting goals of reducing waste;
3. Sponsor educational seminars about waste management and mercury reduction;
4. Participate in an Environmental Leadership Council, a group comprised of hospital leaders, EPA officials, environmental groups, and others that will provide recommendations to the AHA about educational and outreach activities to hospitals, health systems and health care workers to help reach these waste reduction goals; and
5. Develop Internet-based model waste minimization plans for hospitals targeted at specific chemicals.

If the goals of this program are realized, mercury pollution from many health care facilities will be minimized by the year 2005. The AHA presently has a membership of 5,000 hospitals, health care systems, networks and other care providers.

### **Quantity and Estimated Uncertainty**

In July 1993, the previous New Jersey Mercury Task Force estimated that regulated medical waste comprised approximately 30% of the total hospital waste.<sup>178</sup> The total quantity of regulated medical waste reported, based on 1991 figures, was approximately 17,000 tons. The total amount of regulated medical waste generated in New Jersey in 1999 is approximately 70,770 tons according to the Bureau of Resource Recovery and Technical Programs.<sup>179</sup> Of this quantity, 34,550 tons were managed by incineration or landfilling for final disposal. The large increase in the amount of regulated medical waste generated in the State between 1991 and 1999 is not necessarily due to increased waste production. Rather, a substantial proportion of the apparent increase may be the result of better reporting and record keeping related to medical waste within the State.

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<sup>178</sup> New Jersey Department of Environmental Protection and Energy. Final Report on Municipal Solid Waste Incineration. Volume III, Technical And Regulatory Issues. July 1993.

<sup>179</sup> 1999 Annual Regulated Medical Waste Generator and Transporter Reports, data provided by the NJDEP Bureau of Resource Recovery and Technical Programs. Data is reported from generators and transporters and has not been verified.

Analysis of New Jersey-generated Regulated Medical Waste Disposition (tons)  
(source: data from the RMW Annual Generator Reports for 1999)

Total RMW generated in NJ 1999	70,770
Portion managed via sewer disposal (liquids)(est.)	36,220
Portion incinerated or landfilled	34,550
Portion processed on-site in NJ.	
Incineration	831
Alternative technology	6,523
Total	7,354

It should be noted that mercury contained in sewer-disposed liquids has been accounted for in the sludge write-up contained in this report. Likewise, mercury released by incineration and that disposed of in landfills is accounted for in specific write-ups elsewhere in this report.

The quantity (i.e., average concentration) of mercury in New Jersey's medical waste has not been quantified. However, Volland has calculated an average mercury concentration of 15 ppm in medical waste incinerated by medical waste incinerators monitored during performance tests conducted by the California Air Resources Board from 1987 to 1989.<sup>180</sup> Using a maximum mercury concentration of 15 ppm for the regulated medical waste generated in New Jersey, approximately 1036 pounds of mercury is disposed of annually. The Task Force believes that the mercury content of regulated medical waste generated in New Jersey is significantly less than 15 ppm for several reasons. First, the data used by Volland were collected more than 10 years ago. Since that time, the medical industry, and hospitals in particular, have become more aware of the presence of mercury in its waste streams. Source separation programs such as battery and fluorescent lamp collection and recycling programs implemented at hospitals remove several of the high-mercury contributors from the medical industry waste stream. Second, many alternatives to mercury-containing products have been developed in the last 10 years. Use of these mercury-free products results in decreased mercury in the waste produced. Considering these waste reduction measures, the Task Force estimates the present average mercury concentration of regulated medical waste is closer to 5 ppm than to 15 ppm. It should be emphasized that the 5 ppm average is an estimate only. The Task Force has no data to support this estimate. Calculations based on this 5 ppm assumption indicate that approximately pounds of mercury are disposed of as a component of the regulated medical waste streams generated in New Jersey.

### **Sectors Affected**

The facilities that process medical waste using the methods described herein would be affected by efforts targeting this sector.

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<sup>180</sup> Volland, C. Emission of Volatile Heavy Metals from Medical Waste Incinerators. *Proceedings of the 85<sup>th</sup> Annual Meeting & Exhibition of the Air & Waste Management Association*, Kansas City, Missouri, 1992.

## **Receiving Media**

The distribution of mercury to the environment as a result of the disposal of regulated medical waste is dependent upon the disposal method. Medical waste that is incinerated, or otherwise heat treated, will release mercury and mercury compounds primarily to the atmosphere, although some mercury will be scrubbed out of the gas stream by air pollution control devices and sent to landfills. Medical waste that is sent directly to landfills for disposal can release mercury to soil and/or groundwater. Finally, sewer disposal of medical waste that contains mercury can release mercury to water or to the sludge produced during wastewater treatment. The RMW disposed of in municipal wastewater (sewerage) systems is comprised largely of blood and blood products, biological production wastes and funeral home discharges. This liquid RMW likely contains little added mercury from anthropogenic sources.

Mercury releases from New Jersey medical waste incinerators, municipal solid waste incinerators, landfills, in wastewater, and in wastewater treatment sludge are accounted for in the inventories discussed in other sections of this document.

The approximately 7,354 tons incinerated and treated using alternative technologies could provide a mercury source for atmospheric or surface water deposition. Some of the amount processed using alternative technologies would be incinerated at municipal waste incinerators or landfilled in state, while some would be disposed of out of state.

## **Chemical Species**

Mercury in medical devices such as thermometers, manometers and thermostats exists as elemental mercury. Dental amalgam also contains mercury in the elemental form. Mercury in laboratory reagents is in the form of compounds, both organic and inorganic. Examples include mercury iodide, mercury chloride, mercury oxide, mercury nitrate and mercury sulfate. Batteries used in pacemakers, hearing aids and equipment such as defibrillators contain mercuric oxide. Plastic pigments may contain cadmium-mercury compounds and it has been reported that the red pigment and black print used in red bags also contain mercury.<sup>181</sup> As previously mentioned, medical waste incinerators are suspected of emitting mercury as mercuric chloride due to the reaction of mercury and chlorine components of plastics and packaging that make up this waste stream.

## **Reduction Options and Associated Costs and Impediments**

### *Source Reduction*

The primary opportunity for reduction of mercury from medical facilities is for the facilities to purchase and use mercury-free products. Alternatives exist for many of the products, instruments and components identified for this source category. However, it is up to the

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<sup>181</sup> Florida Center of Solid and Hazardous Waste Management, Mercury in Florida's Medical Facilities: Issues and Alternatives. Report #S-97-15, December 1997.

individual facility to voluntarily institute the necessary controls to screen purchased items. Smaller facilities are at a disadvantage and will be challenged by the effort required to implement such a program. Indeed, these facilities may be unaware that the need even exists. In view of this, successful reduction efforts for smaller facilities should consist of education combined with guidance. All medical facilities, regardless of size, should be encouraged to conduct a mercury inventory that serves as a starting point for reduction efforts.

Additional activities that will result in a reduction of mercury pollution are:

#### *Segregation of waste streams*

An organized approach to waste management will keep hazardous wastes separate from non-hazardous wastes, infectious wastes segregated from other wastes and recyclable wastes separate from non-recyclables. This approach, if implemented properly, will prevent mercury-containing items from being deposited into waste containers that might be sent to disposal facilities not equipped to handle mercury-bearing wastes. Known mercury-containing wastes, such as batteries and fluorescent lamps, should be collected and sent for recycling, where feasible.

1. Medical facilities should procure mercury-containing chemicals in quantities that will be used completely before the shelf life expires. Expired reagents should be disposed of at a proper disposal facility. Out-of-date reagents should not be disposed of by pouring them into a sink or floor drain.
2. Medical facilities should assure mercury spill kits or specialized vacuum devices are available to confine and collect spilled mercury and mercury-containing materials. The materials collected should be sent to a mercury recycler whenever possible. Special, separate containers should be made available for mercury spill clean-up and collection wastes.
3. Implement best management practices.

#### *Control options*

After researching the alternative treatment methods that may be used in New Jersey, the Task Force determined that mercury releases from some of the processes may be possible. For example, microwave treatment of regulated medical waste may heat the waste to temperatures that would drive off mercury. It is not clear at this time whether mercury releases from alternative treatment facilities is an area of concern. It is also unclear whether any alternative treatment facilities operating in New Jersey are equipped with air pollution control devices that collect mercury.

#### **Research, Development, and Monitoring Options**

Research mercury content of regulated medical waste to more accurately determine the potential release of mercury by the various disposal options. In addition, review the operational aspects of alternative treatment facilities and assess the potential for mercury releases from these processes.

## **Outreach and Educational Options**

Efforts directed at educating New Jersey businesses about minimizing potential health risks through mismanaging mercury-containing waste will result in an increased awareness of mercury pollution issues. Outreach efforts should be concentrated on the medium and small medical waste generators that may not currently recognize the potential for mercury pollution that may result from their activities.

## **Recommendations**

- Use mercury-free products in hospital and veterinary and medical offices.
- Segregate mercury-containing waste streams.
- Procure mercury-containing chemicals in quantities that will be used completely before the shelf life expires.
- Manage mercury spills appropriately.
- Research mercury content of regulated medical waste.
- Review the operational aspects of alternative treatment facilities and assess the potential for mercury releases from these processes.



## Dredged Materials Management

### Identification and Description of Source

Dredging in the State of New Jersey directly affects the viability and sustainability of New Jersey's ports and waterways.<sup>182</sup> New Jersey does not consider dredged material to be a solid waste. Dredged materials are, by definition, sediments that are removed from river and bay bottoms in the process of constructing or maintaining maritime infrastructure such as docks, bridges, berthing areas and navigation channels. These sediments are not, by definition, contaminated but can be contaminated with any number of natural and man-made pollutants that have been improperly or imprudently disposed in or near the water. In the Port of NY and NJ, much of the sediment is contaminated. However, elsewhere in the State, dredged materials are relatively clean. As discussed in more detail below, it is estimated that greater than 17,000 pounds of mercury in dredged materials are moved annually by maintenance dredging in the NY/NJ harbor alone.

New Jersey's coastal zone is comprised of a number of natural, cultural and socio-economic environs. Dredging and the management of dredged material vary throughout the coastal zone in response to the specific environmental conditions. To effectively manage dredging and dredged material, it is useful to break the coastal zone into three regions. Region 1 extends from Sandy Hook westward and northward, encompassing the Raritan Bayshore, Newark Bay, New York Harbor and industrialized waterways of the northeastern part of the State. Region 2 encompasses the Atlantic seaboard inclusive of tidal rivers and back bay areas from Sandy Hook south to Cape May. Region 3 encompasses the Delaware estuary from Trenton south to Cape May. These Regions are recognized in the Department's dredging technical manual.<sup>183</sup>

The characteristics of the sediment to be dredged vary among these regions. The methods of dredging and management strategies also vary. In Region 1 most dredging is accomplished by mechanical means (clamshell bucket). The majority of material dredged from this region is either used as remediation material at the Historic Area Remediation Site (HARS) or is beneficially used in remediating contaminated upland sites. The HARS is the site of historical dredged material disposal in the ocean located about 6 miles off of Sandy Hook. The current management strategy for the HARS is to cap previously contaminated dredged material with

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<sup>182</sup> Port and recreational uses of the State's tidal waters add significantly to New Jersey's economy. The Port of New York and New Jersey is the largest container port on the east coast, generating an estimated 166,500 direct and indirect jobs and an estimated 20 billion dollars in regional economic activity (PANJ/NJ, 1999). Along the back bays of the State's Atlantic seaboard, recreational boating and commercial fishing in 1989 contributed in excess of 877 million dollars to the State's economy (NJDEP, 1990). Lastly, the Delaware River supporting the fourth busiest ports on the East Coast contributes an estimated 3.5 billion dollars and 30,000 jobs to the regional economy. In addition to these fiduciary benefits are the less tangible benefits of reduced truck traffic and associated air emissions and infrastructure maintenance. The continuation of these benefits is only possible through dredging to maintain navigability.

<sup>183</sup> NJDEP, 1997, *The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters*, NJDEP, Office of Dredging and Sediment Technology, Trenton, NJ.

three feet of clean dredged material, thereby isolating contaminants from the marine environment. The U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers share responsibility for determining whether material meets the criteria for use as remediation material. Dredged material which is unsuitable for use at the HARS is currently being stabilized and placed on contaminated upland sites as part of an overall remediation or closure strategy for those sites under DEP oversight.

Region 2 exhibits the greatest variability in the management of dredged material. Material in Region 2 may be removed by either mechanical or hydraulic (dredged material slurried with site water and pumped to a disposal location) means. Historically, much of the material dredged from Region 2 had been placed in confined disposal facilities (CDFs) constructed by placing berms on coastal wetlands, and then pumping the dredged material into the enclosure. Recently, more innovative management techniques have been required in Region 2, due in large part to the development of former CDFs, changes in the wetlands regulatory program that make siting new CDFs difficult, and the limited capacity in the remaining CDFs. These emerging management strategies range from use as daily landfill cover, beach nourishment, or general fill as appropriate.

In Region 3 most material is dredged by the Army Corps of Engineers (ACE) by hydraulic means with the material being pumped into large CDFs situated along the Delaware River. However, sandy material is routinely used for beach nourishment or is placed in the Delaware Bay. Privately dredged material is usually dredged by mechanical means and bottom dumped into a rehandling basin, located at the foot of the Commodore Barry Bridge, prior to being pumped up to nearby CDF.

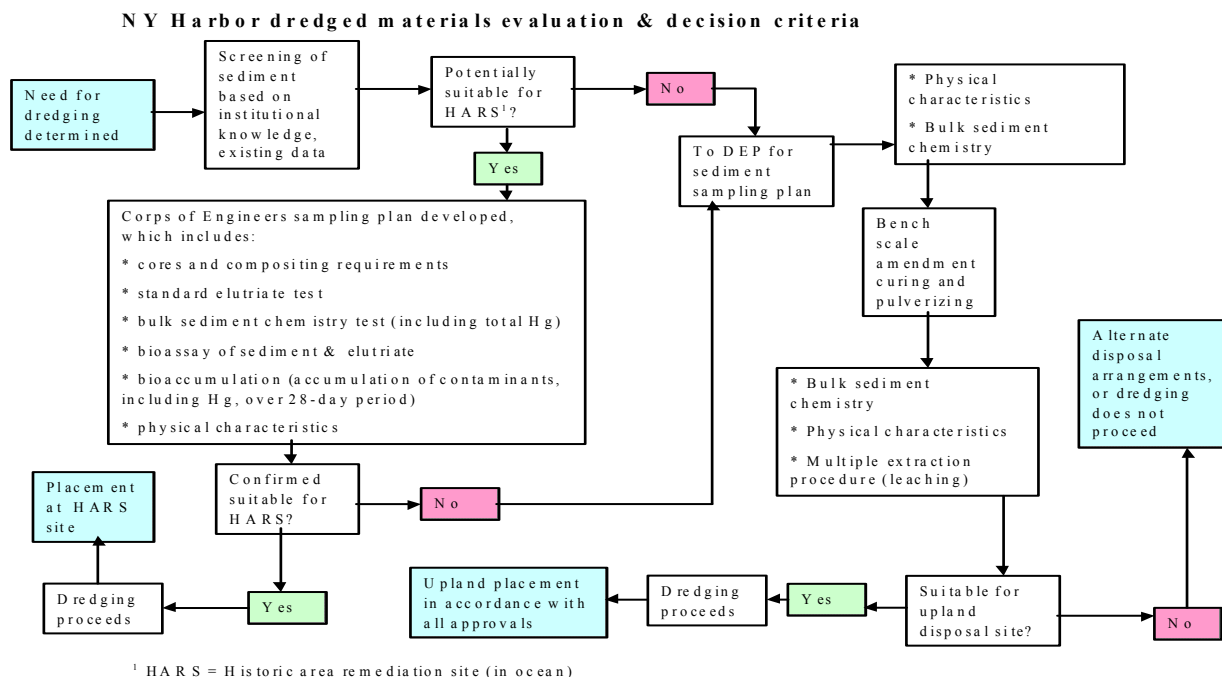
Prior to the issuance of a permit to dredge, the dredged material must be sampled and tested. There are few exceptions for very small scale projects (mostly in Region 2) and projects consisting of 90 percent or greater sand, where analytical testing may not be required. Figures 1 and 2 depict the evaluation and decision criteria that apply to the dredging process and to dredged materials in both the New York/New Jersey Harbor and the Delaware Estuary. Analytical testing required in all three regions includes bulk sediment chemistry (including total mercury), although the analytes may be reduced in some regions based on probability of occurrence (e.g. dioxins and furans). Other analytical tests may also be required, and are determined based on project specific information including the method of dredging (e.g. modified elutriate test for hydraulic dredging) and the proposed end use of the dredged material (e.g. sequential batch leaching test for upland confined disposal, and bioassays for in water disposal).

Excluding dredging for beach replacement, historically an average of 4-6 million cubic yards of sediments have been removed each year from the New York/New Jersey Harbor alone. The material is removed by the U.S Army Corps of Engineers, the Port Authority of New York and New Jersey and by other private entities that require dredging of their berthing areas. However, the amount of material dredged from the State's tidal waterways varies from year to year. In addition, because most contamination of concern in dredged materials results from anthropogenic sources, it is useful to separate new work dredging, (virgin material consisting mostly of rock, sand and clays) from maintenance dredging, (accumulated material consisting

mostly of silts). The projected average annual volume of maintenance dredged material for the next 10 years is about 2.6 million cubic yards.<sup>184</sup>

Based on ocean disposal testing criteria,<sup>185</sup> the majority of this material (75%) removed from the New York/New Jersey Harbor is not suitable for placement at the Historic Area Remediation Site (HARS) off the New Jersey coast.<sup>186</sup> Material not suitable for the HARS is placed on upland sites for brownfield remediation and for construction purposes, such as sub-bases for parking lots, golf courses and other areas where geotechnical fill is required. In order to de-water, stabilize and solidify the dredged material for these purposes, it is almost always mixed with Portland cement, lime or fly ash/kiln dust prior to its land placement. Sediments are also removed from the Delaware Estuary. These materials are typically hydraulically pumped to upland disposal sites in southern New Jersey. Figures 1 and 2 depict the evaluation and decision criteria that apply to the dredging process and to dredged materials in both the New York/New Jersey Harbor and the Delaware Estuary.

**Figure 1. NY/NJ Harbor dredged materials evaluation & decision criteria**

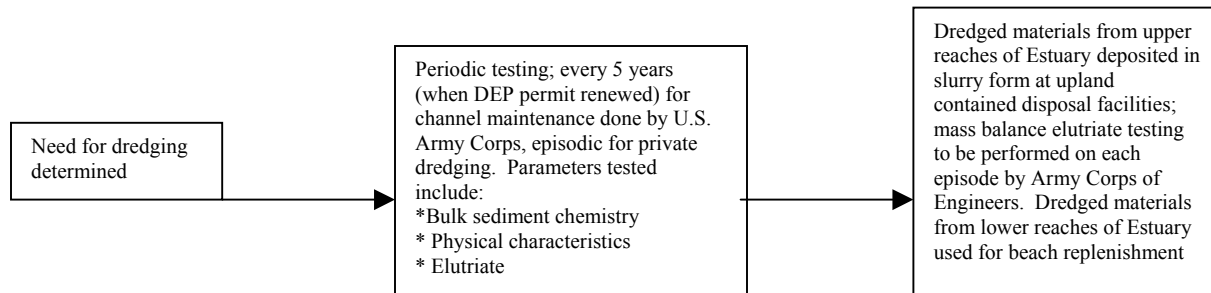


<sup>184</sup> NJDEP, 2000, Office of Dredging and Sediment Technology, Trenton.

<sup>185</sup> These criteria were established by the Environmental Protection Agency Region 2 Office and the New York District of the Corps of Engineers for testing material to be disposed of at the Historic Area Remediation Site (HARS) off the New Jersey coast.

<sup>186</sup> Almost all of the dredged material placed at the HARS contains a measurable amount of mercury; however, it is generally less than 3 ppm total mercury.

**Figure 2. Delaware Estuary dredged materials evaluation & decision criteria**



### Quantity and Estimated Uncertainty

Sediment sampling has shown that typical dredged material contains mercury at widely varying concentrations depending on where it came from and at what depth dredging took place. Based on sediment sampling conducted by the National Oceanic and Atmospheric Administration (NOAA), the average concentration of mercury in New York Harbor sediment is estimated to be 2.88 parts per million (PPM).<sup>187</sup> An independent review of sediment sampling results from 16 project reaches in the New York/New Jersey Harbor region, comprising a total of 120 analytical samples, found a mean mercury concentration in sediments of 2.09 ppm.<sup>188</sup> This research found the lowest average concentration (0.388 ppm) in Kill Van Kull, and the highest average concentration (6.24 ppm) in Arthur Kill. Sediment in the Delaware Estuary has been found to be considerably lower in mercury content; the average sediment mercury concentration from 81 stations was found to be 0.14 ppm.<sup>189</sup>

Multiplying the tonnage of dredged material by the average concentration of mercury yields a total in excess of 17,000 lbs. of mercury being moved annually by maintenance dredging in the New York Harbor alone.

There are a number of possible routes where mercury in dredged materials could reach the environment. Figure 3 depicts these routes for a typical NY/NJ Harbor dredging process with upland disposal.

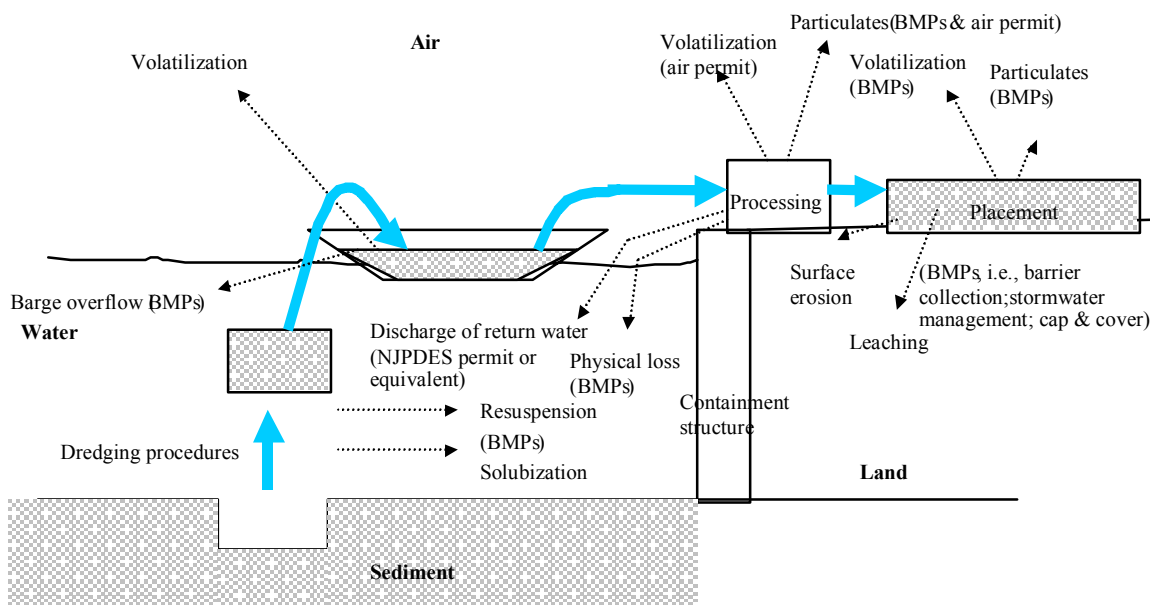
<sup>187</sup> NOAA, 1994 REMAP sediment sampling and characterization effort.

<sup>188</sup> NJDEP, 2000, Office of Dredging and Sediment Technology, Site Remediation Program, PO Box 028, Trenton, NJ.

<sup>189</sup> National Oceanic and Atmospheric Administration (NOAA), 1998, Draft data for the Mid-Atlantic Integrated Assessment (MAIA).

One such route is the dredging process itself. The emission of mercury to air should be trivial during the dredging process. But there is a potential effect on the water body being dredged during the dredging activity when some sediment particles may fall off from the chunk of dredged material. These resuspended particles may contain mercury. Based on recent work by Feng et al. (1999) in the Hudson River estuary<sup>190</sup>, the residence time of suspended particles in the water column ranged from <1 to 10 days. However, it has been found that in most areas of the

**Figure 3. Mercury in Dredged Materials: Possible Transfer Routes and Associated Controls (in parentheses)**



Hudson estuary the residence time of particles is <1 to 2 days. So, these particles normally quickly sink to the bottom. However, Feng et al. (1999) also reported that during a tidal cycle in the Hudson River estuary, the suspended particles can be transported as far as 15 kilometers from the dredging site.

There remains some question as to whether the dredging activities could increase the availability of mercury to fish and other aquatic organisms. In one study involving a model simulating the uptake of mercury in fish resulting from upstream dredging, a 30% increase in mercury concentration in pike was predicted.<sup>191</sup>

<sup>190</sup>Feng, H. and J. K. Cochran and D. J. Hirschberg. 1999. <sup>234</sup>Th and <sup>7</sup>Be as tracers for the transport and dynamics of suspended particles in a partially mixed estuary. *Geochimica et Cosmochimica Acta*, 63, 2487-2505.

<sup>191</sup>Schultz, Titta, P. Korhonen, and M. Virtanen, 1995, A mercury model used for assessment of dredging impacts, *Water, Air and Soil Pollution* 80, 1171-1180.

Another potential source of mercury release to the environment could be the processing step, where materials such as Portland cement are mixed with the dredged materials to stabilize and solidify it. It currently is not known how much mercury is released to the air during this mixing. Because the process is exothermic (heat releasing), mercury could be volatilized at that time; but how much this would increase the annual release rate is unknown. Pursuant to NJDEP air permits, a mass-balance comparison of mercury concentrations in unprocessed and processed materials will be performed at an upland disposal operation expected to be underway by the fall of 2000. Results of this process should indicate whether a large discrepancy exists, which would signal a potentially significant air emission.

Another potential release source is the placement site itself. In order to estimate the potential for air emissions from the mercury contained in dredged material at placement sites, two estimates were calculated. Both assumed that six million cubic yards of dredged material is generated statewide each year and that 75% of it is placed on the land.<sup>192</sup> Both also assumed the solid content of dredged material is 40% (it generally ranges from 30% to 40%) and that the volatilization rates under wind velocity of 5 – 35 km/hr are respectively 0.0047-0.0055%, based on a 7-day cycle of replenishment of new materials on the placement site and 0.0066-0.0082% based on a 3-day cycle. Based on these rates, if mercury concentration in the dredged materials is assumed to average 2.88 ppm, a volatilization rate of 0.23-0.28 kg/y (0.51-0.62 lbs./yr.) is predicted with a 7-day cycle. If the cycle is 3 days, the predicted rate is 0.33-0.41 kg/y (0.73-0.90 lbs./yr.).<sup>193</sup> There is a high degree of uncertainty in both of these estimates, but they should represent an approximation of mercury volatilization if one ignores the stabilization/solidification process.

Mercury that is not emitted to the air can remain in the dredged material regardless of whether or not the dredged material is stabilized. However, within the dredged material, mercury can diffuse from high concentration areas to low concentration areas through pore spaces due to molecular diffusion processes. The rate of this diffusion depends upon the moisture content of the material. Therefore, during heavy rain events, rainwater may penetrate through the dredged material and get into the ground. If this is the case, a certain amount of mercury may be transported into the ground. The amount of mercury getting into the ground depends on many factors such as the porosity of ground soils, concentrations of mercury in the dredged material and the amount of rainwater, as well as the mercury partitioning between the solid and liquid phase. Relatively speaking, however, the concentration of mercury in the water entering the ground would be quite a bit lower than that in the dredged material.<sup>194</sup> Further, in the New York

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<sup>192</sup>These “worst case” estimates are based on conversations with members of the Dredge Team in Region 2 of the U.S. Environment Protection Agency. Since the vast majority of material dredged in New Jersey is represented by the 4-6 million cubic yards removed each year from New York/New Jersey Harbor, a statewide maximum estimate of 6 million cubic yards was used to calculate mercury releases to the air. Similarly, since 50%-75% of this dredged material is disposed of on the land, the higher figure was used for calculation purposes.

<sup>193</sup>H. Feng, Ph.D., 2000, Model calculations based on realistic assumptions, H. Feng, Department of Earth and Environmental Studies, Montclair State University, Upper Montclair, NJ 07043.

<sup>194</sup>H. Feng, Montclair State Univ.

Harbor area where mercury concentrations in dredged material are the highest, dredged material placement sites are designed with engineering controls including groundwater containment and/or leachate collection.

For most of the potential mercury release routes, best management practices (BMPs) are in place to minimize releases and other problems. These BMPs are summarized below:

#### Standard Dredging Site Best Management Practices for Work in the New York Harbor

- Dredging to be accomplished with a closed “environmental” clamshell bucket dredge (minimizes the loss of water and sediments from the bucket during lift).
- Dredged to be operated so as to maximize the “bite” of the clamshell (fewer trips through the water column).
- Dredge bucket lift speed shall not exceed two feet per second (minimizes loss of material during lift).
- Dredged material to be deliberately placed in the scow (minimizes loss of material during transfer of material and splashing of material out of the scow).
- No barge overflow (prevents the discharge of sediment-laden water from the scow back to the water).
- All scow are to be permanently sealed or of solid hull construction (eliminates the potential loss of material through the split-hull scow (bottom) doors).
- No hosing or rinsing of the gunwales or sides of the scows during dredging (reduces the resuspension of material lost from the scows during transfer).
- Dredging only on flood (or ebb) tide depending on contaminated sediment patterns in the waterway being dredged.
- Silt curtains to be deployed where maximum current velocity does not exceed 1 knot (controls resuspended sediment around the operating dredge).
- Dredging to be accomplished to a uniform depth so as not to create anoxic holes in the channel bottom.
- Standard Best Management Practices and Regulatory Approval Conditions Applied to the Processing Facility.
- Use of spill plate between the scow and the bulkhead during unloading of dredged material (keeps material spilled out of the bucket during unloading from entering the water).
- Routine sweeping (frequency to be specified) of the unloading area and reintroduction of all spilled material into the product stream (reduces the potential for sediment to reenter the waterway).
- Stormwater management requiring full capture, containment and treatment of the 1-year storm prior to discharge of stormwater from the unloading/processing area (minimizes the loss of sediment into the water associated with stormwater runoff).
- Discharges of return water or decant water regulated by either a NJPDES permit or a Water Quality Certificate. Permits routinely require minimum retention or settling times, monitoring requirements for constituents of concern and total suspended solids with action levels prior to discharge. A NJPDES Permit allows for the discharge of return water from a different waterway at the processing site. WQC is issued for those facilities

discharging into the same waterbody from where the dredged material originated. A WQC includes the same settling times, monitoring conditions and/or action levels as a NJPDES DSW permit.

- Air discharges regulated under Air Pollution Control Permit. Permit conditions now include fugitive emission control, intake limits on constituents of concern and preliminary bulk sediment testing for total Mercury at both the intake of the processing plant as well as on the processed (adjusted for residence time in the pug mill) material. This testing is done to detect any potential volatilization of Mercury during processing. If a loss is detected, more sophisticated monitoring and controls may be required.

#### **Best Management Practices and Controls Employed at the Placement Site**

The placement sites are subject to DEP oversight, either Site Remediation Program or Bureau of Landfill Engineering. The sites must have an approved remedial action work plan or landfill closure design. These approved plans typically include the following:

- Groundwater containment, collection and / or treatment to be installed prior to accepting dredged material (these systems prevent potential release of contaminants to groundwater).
- Requirements for stormwater management during closure including capture and treatment of stormwater from the site (prevents erosion of material from the site).
- Clean fill cap or other cover (prevents long term exposure of dredged material to the air, reducing or eliminating long-term volatilization and particulate emissions).

In addition, the following best management practices are employed at the site:

- Processed dredged material is placed on the site in one-foot lifts (for compaction purposes so that the desired density for future site construction and/or development is achieved).
- Processed dredged material is placed while still wet after processing to help keep fugitive dust to a minimum. Even after placement, the material is kept wet by water trucks which are in continuous operation to control fugitive dust.
- Processed dredged material cannot be placed during periods of heavy rainfall.
- The slopes of the placement site must be such that the processed dredged material does not slough away from the area where it is placed.
- Vehicle traffic over and in the area of freshly placed processed dredged material must be minimized so that the material has a chance to dry and thus stabilize in the area where it is placed. This reduces the chance that the material can become airborne.

#### **Receiving Media**

Potential receiving media are discussed above, and depicted in Figure 3.

#### **Chemical Species**

Chemical species are unknown. Mercury is believed to exist in sediments primarily as the virtually insoluble compound, HgS. However some exists in other forms, including methylated species, and may be bound within organic matrices in biota or within detritus. Species of mercury that could be emitted from processing or at other locations are not known.



## **Reduction Options and Associated Costs and Impediments**

Follow the above best management practices to minimize volume and loss and to maximize containment at sites with minimal environmental impact.

## **Research, Development, and Monitoring Options**

The DEP, with input from the Office of New Jersey Maritime Resources, the U.S. Army Corps of Engineers, and the U.S. EPA, should complete a review of literature regarding potential increases in bioavailability from solubilization and resuspension into the water column during the dredging process and from processing and land placement. Any such increases expected should be compared with potential bioavailability from sediments if left in place. The outcome of the review should be the ascertainment of whether a need for additional research or monitoring is warranted.

If necessary, based on literature review or additional data, the DEP, with input from the organizations listed above, should formulate recommendations for upgrades to dredging procedures and equipment to the best reasonably available methods to minimize any solubilization or resuspension that may occur.

The DEP should perform a mass-balance comparison of mercury concentrations in unprocessed and processed materials. Results of this process should indicate whether a large discrepancy exists, which would signal a potentially significant air emission.

Measure, either at laboratory or field scale, releases to air and water from stabilization processing site(s) and upland placement site(s). If such releases appear significant, review and improve procedures to ensure that significant volatilization or other releases do not occur.

## **Outreach and Educational Options**

Continue dialogue with policy makers, educators, industry and the public to increase understanding of the issue and the need for basing decisions on sound science.

## **Recommendations**

- Research releases during handling and stabilization.
- Clarify potential releases from the dredging itself.
- Modify federal legislation that currently prevents the use of the latest dredging technology because the equipment is not manufactured in the U.S.
- Continue to manage and monitor upland placement sites.

# **Hazardous Waste Incineration**

## **Identification and Description of Source**

A hazardous waste incinerator is a unit that thermally treats hazardous wastes for reducing the volume and toxicity of the waste. The facilities generally have the capability of treating wastes in one or more of the following states: solids, liquids, sludges and gases. A typical incinerator consists of three major components: a waste feed unit (rotary kiln, liquid injection unit, etc.), an afterburner or secondary combustion chamber and an air pollution control system. Wastes in solid or sludge form are fed to the rotary kiln portion of the incinerator. Liquid and gaseous wastes may be fed to either the rotary kiln or directly to the afterburner, depending on the configuration of the equipment. Gases produced by the incineration process pass from the feed unit to the afterburner where any remaining organic materials are combusted, and then through the air pollution control system. The air pollution control system removes or neutralizes particulate, heavy metals, acid gases and sulfur dioxide from the gas stream before it is discharged through a stack to the atmosphere. Residuals generated by the incineration process are ash from the solids incinerated and sludge produced from treatment of the water used in the air pollution control system. Both of these residual materials are collected and treated as a hazardous waste and shipped to a hazardous waste landfill.

The wastes that can be treated by incineration, including those that contain mercury, are limited by federal regulations. These regulations may be found at 40 CFR Part 268, commonly referred to as the Land Disposal Restrictions. During the initial waste approval process, wastes that contain high levels of mercury are not acceptable for incineration. In addition, the EPA policy of impermissible dilution, which prohibits combustion of certain inorganic metal-bearing wastes, serves to direct mercury-contaminated inorganic wastes to reclaiming and/or recycling facilities and away from hazardous waste incinerators.

## **Quantity and Estimated Uncertainty**

Prior to May 2001, there were five operating hazardous waste incinerators in New Jersey. Four of these were non-commercial. In a press release issued January 31, 2001, the only commercial hazardous waste incinerator operating in New Jersey announced that it would cease operation as of May 8, 2001, and that it would stop receiving wastes on April 30, 2001. One of the remaining four non-commercial incinerators is believed to emit less than 0.5 lbs./yr. of mercury. The three remaining units are believed to emit less than 12 lb./yr. mercury.<sup>195</sup> Up until May 8, 2001, the quantity of mercury released as of the year 2000, from the one commercial incinerator has been estimated to be approximately 50 pounds per year. Therefore, the total emissions of mercury from the 3 non-commercial and the one former commercial incinerator for the year 2000 are estimated to be 62 lbs. per year. This estimate may vary by an estimated 10 to 15 % depending on the mercury concentrations and volume of waste incinerated.

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<sup>195</sup> USEPA Region II data files, 2001.

Work by the first New Jersey mercury task force indicates that releases of mercury from municipal solid waste combustion ash are low.<sup>196</sup> To the extent that the chemistry of the ash and its disposal environment are similar for hazardous waste ash, mercury emissions should likewise be low.

### **Sectors Affected**

Efforts to limit emissions from this sector would affect the incinerating facilities themselves, as well as generators of hazardous waste that ship their wastes to be incinerated.

### **Receiving Media**

The chief receiving medium is believed to be air due to the volatility of mercury and mercury compounds. Mercury may also be transferred off-site to hazardous waste landfills as components of ash and sludge, but the amounts are assumed to be minimal due to the inherent volatility and method of treatment.

### **Chemical Species**

The chemical species of mercury released from combustion units, including hazardous waste incinerators, is difficult to quantify precisely. It is generally assumed that elemental mercury, when present, is volatilized during combustion and released as elemental mercury. The species of mercury released from waste materials containing mercury bound in both organic and inorganic matrices is less certain, and probably consists of a combination of elemental, oxidized and mercury salt forms.

### **Reduction Options and Associated Costs and Impediments**

There are three major potential control strategies for mercury at hazardous waste incineration facilities. The most important strategy is the continued segregation of high-mercury compounds from the waste that is to be incinerated. Wastes reported to contain high levels of mercury are refused for treatment and routed to reclaiming facilities or other approved treatment and disposal operations.

#### *Source Reduction*

Mercury is not used directly in the incineration process, and source reduction opportunities are not available through a modification of the incinerator facility or process. The primary emphasis for mercury source reduction from this industry lies with the generators of hazardous waste. Mercury incorporated into products during the manufacturing processes is present in off-specification batches, spill clean-up wastes and product returns that are disposed via incineration. Thus, elimination or reduction of mercury used in manufacturing processes will result in a

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<sup>196</sup> New Jersey Department of Environmental Protection & Energy, 1993, *Task Force on Mercury Emissions Standard Setting, Final Report on Municipal Solid Waste Incineration, Volume III, Technical and Regulatory Issues*, Chapter 11, Environmental Effects of Mercury Control on the Solid Waste Stream, pp. 11.1 to 11.10, NJDEP, Trenton, NJ, July, 1993.

decline in the mercury content of wastes produced and a commensurate decrease in the emissions from the incineration of these wastes.

### *Control Options*

A second option for mercury reduction is to transfer mercury-bearing wastes to mercury recovery facilities instead of treating the wastes by incineration. Inorganic mercury-containing wastes at almost any concentration can be treated, but the economics of recovery of low concentrations of mercury are usually cause to select another treatment option. In addition, mercury reclaimers generally cannot recover mercury from organic compounds and this limitation is another reason these wastes are sent to incinerators.

The third option for reducing mercury emissions from hazardous waste incinerators is the use of add-on control devices to remove mercury from the gas stream exiting the unit. Presently, several systems that use carbon injection or carbon fluidized bed technology appear to be the most effective for mercury removal.

Under the new Air/RCRA MACT rule promulgated by EPA, allowable mercury emissions from hazardous waste incinerators are to be decreased to 130 micrograms per dry standard cubic meter. At this time it is unclear as to whether this lower emissions level will require the incinerator to install new controls to meet this limit.

### **Research, Development, and Monitoring Options**

Little is known about the speciation of mercury emitted from hazardous waste incinerators. Research directed at confirming the type and quantity of mercurial compounds produced would allow for a more thorough understanding of how mercury from combustion sources enters and cycles through the environment. In turn, the risks posed by emissions from combustion could be quantified more accurately.

### **Outreach and Educational Options**

Outreach and educational efforts aimed at general mercury reduction strategies will indirectly affect the emissions from the commercial incinerator receiving these wastes. As stated earlier, a reduction in the use of mercury as a raw material will have a direct impact on the quantity of mercury presented to incinerators for treatment. Efforts directed at discouraging non-essential mercury use will be useful in an overall mercury pollution prevention program.

### **Recommendations**

- Eliminate or reduce mercury used in manufacturing processes.
- Continue to keep wastes having high mercury content out of the incineration stream.
- Transfer mercury-bearing wastes to mercury recovery facilities.
- Add mercury control devices to hazardous waste incinerators.
- Confirm the type and quantity of mercurial compounds produced by incineration.

- Encourage the general reduction of use of mercury as a raw material.

## Hazardous Waste Sites

### Identification and Description of Source

Since the 1970s, New Jersey and the New Jersey Department of Environmental Protection have been at the forefront of identifying and characterizing hazardous waste sites. New Jersey has more sites on the National Priorities List (about 10% of the total) than any other state. To date, a total of thirty-eight mercury-contaminated sites have been reported. The sites are listed based on exceedence of ground water quality criteria or soil guidance criteria.<sup>197,198</sup> Fifty percent of the sites had contamination in both soils and ground water, while the remainder had only ground water contamination. Of the sites reporting both soil and ground water contamination, 90.5 % of the sites were located in northern and central New Jersey, reflecting the greater degree of industrialization in the northern part of the state. A total of fifteen sites had only ground water impacted by mercury contamination, and these sites were all located in the southern part of the state. Of these 15 sites all but one involved contaminated potable drinking water wellfields. Free product mercury has been found at the Atlantic City Air National Guard Facility, former Du Pont Chemical Pompton Lakes explosives works, Ewing Navel Air Warfare Center, and the Albee Development site in Hoboken.

Soil contamination by mercury is generally not characteristic of an entire site. Generally soil contamination is limited within a site to certain areas of concern commonly referred to as hot spots. However, the Du Pont Chemical Pompton Lakes facility, Troy Chemical Site (Newark), Ventron/Velsicol (Berry's Creek area in Bergen County), and LCP Chemical Inc. Site (Linden), show more of a site-wide pattern of soil contamination by mercury. Soil contamination (where detected) ranged from 0.68 ppm to 34,700 ppm. Five sites with soil contamination had soil levels of mercury in excess of 1,000 ppm.

Ground water contamination at sites can be transported horizontally and thus can be more of a site-wide problem. Ground water levels (where detected) ranged from below the drinking water maximum contaminant level (MCL) of 2 ppb to 2,250 ppb. This latter high figure was observed at Cosan Chemical Company near the locus of Berry's Creek. The specific groundwater values for the south Jersey wellfield sites were not provided at the time of the case manager survey. Surface water sediments ranged from 0.35 ppm to a high of 60,000 ppm, and included both fresh and salt water systems.

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<sup>197</sup> In New Jersey, the Ground Water Quality Standard for mercury is 2µg/L (2ppb). The residential Soil Guidance Criteria for mercury is 14 mg/kg (14 ppm) and the Industrial soil guidance criteria for mercury is 270 mg/kg or 270 ppm. These human-health based values are based on total mercury and do not consider speciation.

<sup>198</sup> Any sites which show exceedence of the criteria numbers should be listed within the inventory of mercury contaminated sites. The Site Remediation Program (SRP) has no contaminant specific data base, so that the information collected herein was acquired by a general request for case managers with mercury contaminated sites to respond with general information relevant to mercury contamination at their sites. Thus we cannot be sure this list is comprehensive. In some instances the sites also reported surface water and sediment contamination.

Air emissions of mercury have been measured at the Ventron/Velsicol site, with levels as high as 60.6 ng/m<sup>3</sup>. In recent years gentrification in Hoboken (Hudson County) has included two attempted conversions of former fluorescent bulb factories to multiple family condominium units. In both instances occult globules of residual mercury led to mercury levels in ambient air in excess of health standards.

Remediation at these sites has been limited since many are still being investigated. Capping has been planned for some sites, while vacuum collection has been the remediation technique at sites with free elemental mercury. At the Merck Facility thermal treatment with carbon absorption has been used to remove mercury from contaminated soils.

### **Quantity and Estimated Uncertainty**

No estimates have been made of the quantities of mercury that may be leaving the identified sites and entering the ambient environment. Any such quantities are believed to be low. For purposes of this report, a yearly emission to the ambient environment of 10 pounds or less is assumed.

### **Sectors Affected**

Individual sites could be affected by measures to reduce mercury releases to the environment.

### **Receiving Media**

Releases could enter the air, adjacent water bodies, or surrounding soils and sediments.

### **Chemical Species**

Chemical species are likely to be highly varied, and include elemental mercury and a wide variety of mercury compounds.

### **Reduction Options and Associated Costs and Impediments**

The listed sites are included in the NJDEP's overall plans for hazardous site clean-ups; options and costs are determined and managed on a case-specific basis.

### **Research, Development, Monitoring, and Outreach and Educational Options**

Although no data exist to indicate that releases of mercury from hazardous sites to the ambient environment occur in significant quantities, further data would be useful. Air monitoring at selected sites could be particularly informative. In general, a more holistic view of sites should be considered, with attention given to possible transport of mercury contamination beyond the site boundaries.

### **Recommendations**

- Monitor air emissions at selected sites to ascertain occurrence of significant releases to the environment.



## Landfill Gas

### Identification and Description of Source

There are an estimated 475 million cubic yards of solid waste deposited in the 578 known and suspected landfills in New Jersey.<sup>199</sup> With the assumption that the mercury content of the deposited solid waste is approximately 2.5 ppm<sup>200</sup>, and that a cubic yard of compacted solid waste weighs 1000 pounds, the waste in place in New Jersey contains approximately 1.2 million pounds of mercury. Clearly, if even a modest percentage of this mercury is emitted, the quantity emitted would be significant. As solid waste decays, it releases gas. Landfill gas is approximately 50% CO<sub>2</sub> and 50% CH<sub>4</sub>. Other compounds are present, including trace quantities of gaseous mercury species. Over half of the landfill gas generated by New Jersey landfills is burned, either in flares or for energy production.<sup>201</sup> Burning landfill gas might change the chemical species of any emitted mercury, but would not reduce the total quantity of emitted mercury.

### Quantity and Estimated Uncertainty

A formula has been developed by the USEPA to estimate the emission of gas from landfills. This formula, used in conjunction with specific dates of operation and rates of waste deposition for the known New Jersey landfills,<sup>202</sup> suggests that approximately 1.7 billion cubic meters of gas per year are produced from New Jersey landfills.<sup>203</sup> Stack test data exist on the concentrations of mercury in landfill gas from several landfills in the New Jersey region.<sup>204</sup> These data indicate an

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<sup>199</sup> Information received from the NJDEP, Division of Solid and Hazardous Waste, January 1999, indicates the total 1997 volume of waste in place in 98 NJ landfills of greater than 100,000 cubic yards in volume was approximately 415 million cubic yards. An additional 60 million cubic yards is estimated by NJDEP/DSR&T to be present in an additional 300 landfills smaller than 100,000 cubic yards.

<sup>200</sup> NJDEP, 1993, *Task Force on Mercury Emissions Standard Setting, Vol. III*, Chapter 1, NJDEP, Trenton, NJ 08625.

<sup>201</sup> Based on information received from NJDEP Division of Solid and Hazardous Waste, 7/99, estimated landfill gas emissions, and estimated collection and combustion efficiency.

<sup>202</sup> Information received from NJDEP, Division of Solid and Hazardous Waste, January 1999.

<sup>203</sup> Formula used is first-order decay formula from: USEPA, 1996, *Turning a Liability into an Asset*, EPA 430-B-96-0004. This formula is  $CH_4 \text{ ft}^3/\text{yr} = Lo \cdot H \cdot R \cdot H(e^{-kc} - e^{-kt})$ . The "c" is time in years since closure of the landfill; "t" is time in years since opening. Input values of  $k = 0.04/\text{yr}$  and  $Lo = 1.765 \text{ cf/lb.}$  were used, along with site specific data and estimates. This formula generates a volume, in cubic feet per year, of release of methane, which then is multiplied by 2 to estimate the total gaseous emission in cubic feet, and converted to cubic meters.

<sup>204</sup> The average mercury concentration in a series of stack tests performed at three landfills in New Jersey, the Ocean County LF, Fort Dix LF, and Edgeboro LF, and the Fresh Kills LF in Staten Island, NY, NY, is in the range of 5 to 10  $\mu\text{g}/\text{M}^3$ . The reported gas Hg concentrations (in separate sampling events or locations within each landfill) were, for Fresh Kills, 7.32, 17.5, 31.28, and 9.78  $\mu\text{g}/\text{M}^3$ ; for Edgeboro, 0.99, 1.06, and 1.34  $\mu\text{g}/\text{M}^3$ ; for Ocean Co., 2.7  $\mu\text{g}/\text{M}^3$ , and for Ft. Dix, 0.04, 0.16, and 0.3 pounds per year. New Jersey LF data are NJDEP stack test data,

average concentration in the range of 7.5 micrograms (: g) mercury per cubic meter of landfill gas. Multiplying this concentration by the total estimated volume of landfill gas suggests that approximately 30 pounds per year of mercury are emitted from New Jersey landfills.

Another calculation generates a comparable quantity. With this latter method, the mercury emission factor of  $2.9 \times 10^{-4}$  ppm Hg in landfill gas is used.<sup>205</sup> This factor suggests that, in New Jersey, there are approximately 10 pounds of mercury emitted from landfills.<sup>206</sup>

### **Sectors Affected**

Landfills would be affected by any additional control or management efforts.

### **Receiving Media**

The receiving medium is air. Some mercury is also released from landfills in the form of leachate. This release is discussed in another section.

### **Chemical Species**

No information is available on the species of mercury emitted; all concentrations have been expressed as total mercury. If a significant portion of the species emitted are methylated, even the relatively low quantities from this source could be important. A recent study found 50 nanograms of dimethyl mercury per cubic meter in landfill gas.<sup>207</sup> This quantity, if typical of all landfill gas, would translate into what appears to be a relatively insignificant emission of approximately 85 grams (about 0.2 pounds) per year in New Jersey.

### **Reduction Options and Associated Costs and Impediments, and Research, Development, and Monitoring Options**

Mercury going to landfills will be reduced by the removal of mercury from products. Further research should be conducted to determine whether a significant portion of the mercury released from this source is in the form of methyl mercury. The low concentration of mercury in landfill gas in relation to other sources argues that no efforts to control this source are necessary at this time.

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with additional calculations. Fresh Kills data contained in letter from Elizabeth Capdevielle, GSF, Inc., 3321 Bee Caves Rd., Austin TX, to NJDEP, Jan. 3, 1997.

<sup>205</sup>. USEPA, 1997, Mercury Study Report to Congress, Volume II; An Inventory of Anthropogenic Mercury Emissions in the United States, EPA-452/R-97-004, December, 1997, page 3-8.

<sup>206</sup>. Multiplying 1.7 billion M<sup>3</sup> by  $2.9 \times 10^{-10}$  ( $2.9 \times 10^{-4}$  ppm) indicates that about 0.5 M<sup>3</sup> of mercury would be released. Assuming that 1000 ft<sup>3</sup> of methane weighs 42.3 pounds, 1000 ft<sup>3</sup> (28 M<sup>3</sup>) of Hg<sup>0</sup> would weigh 200.59/16 times as much (the ratio of the molecular weights). Therefore, 0.5 M<sup>3</sup> would weigh about 10 pounds.

<sup>207</sup> Lindberg, S.E., et al., 2001, Methylated mercury species in municipal waste landfill gas sampled in Florida, USA, Atmospheric Environment, 35, 4011.

## **Recommendations**

- Reduce mercury in products.
- Analyze landfill gases using state-of-the-art protocols and laboratories to determine mercury species and quantities.

## Landfill Leachate

### Identification and Description of Source

Leachate is liquid discharged from a landfill. Liquids are produced within the landfill through the decay of wastes, and also result from the percolation of precipitation through the landfill surface. Leachate is generated at solid waste landfills including those that are operating and those no longer receiving waste. The newer operating landfills have impermeable liners and leachate collection systems that are designed to prevent the discharge of leachate to the surrounding environment. Many of the older closed (inactive) landfills, however, lack these environmental controls and are, therefore, the most likely sources of mercury discharges. Groundwater monitoring systems are in place at the operating sites as well as at closed facilities that ceased operations after January 1, 1982. Mercury results from groundwater monitoring wells are reported at least once a year under the NJPDES Discharge to Groundwater testing requirements. Approximately 20% of the closed landfills, however, do not monitor for mercury. Landfill leachate itself is not generally tested on a regular basis at the older closed sites.

### Quantity and Estimated Uncertainty

Mercury is currently found in a limited number of monitoring wells at less than 10% of the closed landfills (numbering less than 10 sites) that are reporting data. Recorded amounts are generally in the low parts per billion range. These sites are primarily located in the southern portion of the state.<sup>208</sup> A recent report<sup>209</sup> indicates that about 60% of monitoring wells showed mercury below detection or less than 2 µg/l. About 18% of the monitoring wells had levels > 10 µg/l. About 12.5% of the landfills had one or monitoring wells with a mercury concentration > 20 µg/l. Leachate concentrations from several New Jersey landfills were also reviewed. These included the Sussex County Landfill, the Salem County Utilities Authority Landfill, and the Edgeboro Landfill.<sup>210</sup> These data were either below the detection limit (2 µg/l and 1 µg/l), or estimated to be 0.5 µg/l. Using a value of 5µg/l as conservatively representative of leachate mercury concentration, and assuming that there are about 5000 acres of landfill surface in the state with no leachate collection and that about one half meter of rain infiltrates these surfaces each year and becomes leachate, about 110 pounds of mercury is emitted per year in the form of landfill leachate.<sup>211</sup>

Uncertainty arises in the positive identification of the landfill as the source of the mercury found in some leachate samples and in estimating the overall quantities of the pollutant being discharged to the environment. These uncertainties result from the limited availability of leachate data and the lack of hydrogeologic information at many of the closed landfill sites.

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<sup>208</sup> Based on information received from NJDEP Division of Solid and Hazardous Waste.

<sup>209</sup> Barringer, J., C. MacLeod, and R. Gallagher, 1995, *Distribution of Mercury in Ground Water, Soils, and Sediments of the Kirkwood-Cohansey Aquifer System in the New Jersey Coastal Plain, and Hypotheses as to Potential Sources of the Mercury*, USGS, Mountain View Office Park, West Trenton, NJ 08628.

<sup>210</sup> NJDEP Central File, 1995 NJPDES Permit Discharge Monitoring Reports, NJDEP, Trenton, NJ 08625.

<sup>211</sup> 5000 acres is about 2000 hectares, or  $2 \times 10^7$  m<sup>2</sup>. An infiltration of 0.5 m/yr of rain translates to  $1 \times 10^7$  m<sup>3</sup> of leachate, which is  $1 \times 10^{13}$  g. With a mercury concentration of 5 µg/l,  $5 \times 10^4$  g, or 110 pounds mercury exists in this quantity of leachate.

## **Sectors Affected**

Landfills would be affected by any additional control or management efforts. Many landfills in New Jersey are closed, and are under the jurisdiction of the USEPA or the NJDEP.

## **Receiving Medium**

The main receiving medium is groundwater generally located in the first shallow aquifer underlying the landfill. Any movement of leachate to deeper aquifers or discharge to nearby surface water is dependent upon the hydrogeology of the particular landfill site.

## **Chemical Species**

Mercury results are reported as "total" in the NJPDES groundwater monitoring reports for the landfills. Multiple species may, therefore, be present. The species of mercury in leachate are unknown. Virtually all of the mercury included in aqueous media, including leachate, is likely to be soluble mercury. Water-soluble environmental mercury species include the divalent mercuric ion,  $\text{Hg}^{++}$ , mercuric chloride ( $\text{HgCl}_2$ ), the anionic complexes  $\text{HgX}_3^-$ ,  $\text{HgX}_4^{-2}$ , with  $\text{X} = \text{OH}^-$ ,  $\text{Cl}^-$ , or  $\text{Br}^-$ , and mixed halide complexes such as  $\text{HgCl}_2\text{Br}^-$ ,<sup>212</sup> although some of the total could also be methyl mercury,  $\text{CH}_3\text{Hg}^+$ .

## **Reduction Options and Associated Costs and Impediments**

Capping of closed landfills with impermeable material and the collection of leachate where feasible would serve to minimize discharges of leachate to the surrounding environment. [Acceptance of mercury containing waste in active landfills should continue to be discouraged.]

The installation of an impermeable cap and collection of leachate are options available to the landfill owner under the DSM closure regulations. Difficulties are encountered in obtaining dedicated funding for the closure and post-closure activities at closed landfills, especially those owned by municipalities. Since these landfills are no longer operating, they do not generate revenues. Nevertheless, the municipalities must budget for closure costs and provide dedicated escrow monies for post-closure maintenance and monitoring of the landfill sites over a 30-year post closure period in accordance with the closure regulations. As a result, shortfalls in funding are common.

## **Research, Development, and Monitoring Options**

Groundwater wells at solid waste landfills should continue to be monitored under the NJPDES-DGW program to determine long-term trends for detectable levels of mercury.

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<sup>212</sup>. DeNoble, James P., 1999, Critical Review: *Atmospheric Methylmercury: Sources, Sinks, and Inferences for its De Novo Generation*, DRAFT Masters Thesis, Rutgers University, October, 1999.

### **Outreach and Educational Options**

Landfill owners/operators should continue to be advised of the benefits of landfill monitoring and the necessity for implementation of corrective measures when pollutants are found to be discharging from their sites. More frequent testing of groundwater monitoring wells for mercury could be implemented through the NJPDES-DGW testing requirements for the closed landfill sites.

### **Recommendations**

- Minimize discharges of leachate to the surrounding environment from closed landfills.
- Monitor groundwater wells at solid waste landfills under the NJPDES-DGW program.
- Educate landfill owners on the benefits of landfill monitoring and the necessity for implementing corrective measures.

## Municipal Solid Waste Combustion

### Identification and Description of Source

Solid waste is broadly divided into two major components - Municipal Solid Waste (MSW) and Bulk and Industrial Solid Waste (B/ISW). MSW is generated by residential, commercial and institutional sources within a community. B/ISW is solid waste that cannot be compacted such as tree trunks, appliances (white goods & brown goods), vehicles, scrap metals, construction/demolition waste, and tires. B/ISW also includes residual wastes such as petroleum-contaminated solids, water treatment residues and combustion ash residues. In 1999, 17.2 million tons of solid waste was generated in New Jersey. Table 1 shows 1999 New Jersey solid waste quantities by management method.<sup>213</sup> Much of the tonnage of recycled waste is ferrous metals (e.g., scrapped automobiles) and building demolition and related debris.

Table 1.  
New Jersey 1999 Solid Waste Quantities by Management Method

<b>Management method</b>	<b>Millions of tons</b>
Recycled (total)	<b>9.5</b> <sup>214</sup>
<i>Disposed, incineration</i>	<i>2.1</i>
<i>Disposed, in-state landfill</i>	<i>3.3</i>
<i>Disposed, out-of-state</i>	<i>2.7</i>
Disposed (total)	<b>7.6</b>

The composition of the solid waste for disposal in an MSW incinerator is approximately 95 percent MSW and 5 percent processible BISW. The majority of the BISW, which is not recycled, is landfilled. The majority of solid waste exported for disposal is landfilled.

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<sup>213</sup> The generation data is developed from an aggregation of sources including county weighing/composition studies and USEPA national data. This data is reconciled based on the reporting data for recycling and disposal. The disposal data is developed from the solid waste disposal facility monthly reporting as required in the Solid Waste Regulation at NJAC 7:26. As required, each truck that disposes of waste at a solid waste facility (including transfer stations) must submit an origin and destination (O&D) form which lists the waste types and municipality(s) of origin of the waste. All solid waste disposal facilities have weigh scales and are required to report by waste type, municipality and tonnage. The recycling data is developed from municipalities and end markets reporting. All municipalities are required to report the materials and tonnage of solid waste recycling on an annual basis. This information is supplemented by reporting from the end markets, including the processing or materials recovery facilities. The annual recycling reports are audited by NJDEP. The municipal and county recycling rates are adjusted based on recycling that occurs statewide and is apportioned to the counties.

<sup>214</sup> Much of the tonnage of recycled waste is metals, e.g. scrapped automobiles (1.2 million tons), building and construction demolition and related debris (5.0 million tons), yard waste (1.3 million tons), and various paper grades (1.3 million tons).

MSW contains an estimated  $2 \pm 0.5$  ppm of mercury<sup>215</sup> (see separate write-up on Solid Waste Deposited in Landfills, elsewhere in this document). When this waste is incinerated, some of the mercury contained in the waste is released to the atmosphere.

### Quantity and Estimated Uncertainty

The high temperatures involved in the solid waste incineration process (in the range of 2000° F) can be expected to vaporize virtually all of the mercury present in the waste, regardless of chemical species. Current emission controls on New Jersey solid waste incinerators, which primarily consist of the injection of finely-divided carbon into the particulate control mechanism, remove an estimated 95% or more of the mercury from the combustion exhaust gas stream. The injected carbon is ultimately mixed with the ash. Work by the first New Jersey mercury task force indicates that mercury appears to remain adsorbed on the injected carbon and that mercury releases from municipal solid waste combustion ash are low.<sup>216</sup>

Over the past decade, due to NJDEP requirements<sup>217</sup> that were implemented as a result of the efforts of New Jersey's first Mercury Task Force,<sup>218</sup> these incinerators have installed the carbon injection emission controls noted above. It is also likely that, during this period, the mercury content of MSW has declined due to the virtual elimination of mercury in dry cell batteries, packaging, and other items due to New Jersey laws,<sup>219</sup> national laws, and voluntary reductions of mercury content by manufacturers of some mercury-containing items.<sup>220</sup>

New Jersey's five MSW incinerators are required to report results of stack tests of the mercury concentration of the emitted gas stream on at least a yearly basis. These results are converted to pounds-per-year estimates of mercury emissions. These estimates provide evidence of a consistent and dramatic decline in mercury emissions over the past decade, as shown in Table 2.

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<sup>215</sup> There are two sources of data useful for determining the mercury content of MSW in New Jersey. One source is information on the mercury content of MSW combustion ash; the other is the mercury content of the inlet gas stream at MSW combustion facilities. There is some inconsistency among these data and the resulting calculated mercury content of MSW. The inconsistency may be the result of incomplete volatilization of some mercury-containing items in the MSW waste stream, or variations among the sampling and testing procedures. Overall, a mercury content in the range of 1.5 to 2.5 ppm appears likely.

<sup>216</sup> New Jersey Department of Environmental Protection & Energy, 1993, *Task Force on Mercury Emissions Standard Setting, Final Report on Municipal Solid Waste Incineration, Volume III, Technical and Regulatory Issues*, Chapter 11, Environmental Effects of Mercury Control on the Solid Waste Stream, pp. 11.1 to 11.10, NJDEP, Trenton, NJ, July, 1993.

<sup>217</sup> See, especially, N.J.A.C. 7:27-27.4.

<sup>218</sup> NJDEP, 1993, *Task Force on Mercury Emissions Standard Setting, Final Report on Municipal Solid Waste Incineration*, NJDEP (at that time, NJDEPE), July, 1993.

<sup>219</sup> Especially, the Dry Cell Battery Management Act, N.J.S.A., 13:1E-99.59 through 13:1E-99.81, and the Toxic Packaging Reduction Act, N.J.S.A. 13:1E-99.44 et seq.

<sup>220</sup> As an example, the mercury content in a Philips low mercury fluorescent lamp is 3 mg of mercury per 4-foot lamp. The current industry-reported average is in the range of 10 mg per 4-foot lamp. This industry average has been reduced from 80 mg per 4-foot lamp over the last 10 years.



Table 2.  
Estimated Mercury Emissions from MSW Incineration, Pounds Per Year, 1991 Through 1999

Facility	Facility capacity, tons/year	1991,'92,'93	1996	1997	1998	1999
Camden	451,140	1084	431	350	144	113
Essex	985,500	1771	216	323	115	162
Gloucester	209,875	149	32	51	25	15
Union	562,100	844	84	42	24	32
Warren	160,000	562	4	4	3	4
Total		<b>4410</b>	<b>767</b>	<b>770</b>	<b>311</b>	<b>326</b>

Historically, solid waste has been incinerated in large quantities in urban areas. For example, from the 1920s through the 1970s, quantities in the range of 1 to 1.5 million tons of solid waste were burned each year in the New York metropolitan area.<sup>221</sup> Comparable quantities were likely burned in the Philadelphia area. It can be assumed, based on historical uses of mercury, that this waste contained a quantity of mercury similar to waste today. Because the incineration technology used up to the 1970s had very limited controls on emissions, including particulate emissions, it can be assumed that virtually all of the mercury contained in the incinerated waste was emitted. Much of this mercury emission, which was likely in the range of at least 5000 pounds per year in the New York region alone,<sup>222</sup> could have been deposited relatively close to the sources, which were typically relatively small municipal incinerators and small units in apartment and institutional buildings.

The large reduction in emissions from the solid waste incineration sector that have been achieved over the last decade have lowered the emission to the present estimate of about 300 pounds per year. The magnitude of this reduction provides encouragement that other combustion and combustion-related sources can achieve a similar degree of control.

### **Sectors Affected**

Solid waste incinerators are potentially affected by any additional measures to reduce emissions from this sector. Since all sectors (residential, commercial, industrial, etc.) generate waste, all would be affected as well.

### **Receiving Media**

The receiving medium for the emissions from MSW incinerators is initially air followed by water/land deposition. The residual ash, including bottom ash, grate ash, boiler ash pollution control residue and fly ash (known as combined ash from MSW incinerators) is disposed at

<sup>221</sup> Chillrud, Steven, R. Bopp, et al., 1999, Twentieth century atmospheric metal fluxes into Central Park Lake, New York City, *Env. Sci. Technol.* 33, 657-662.

<sup>222</sup> 1 million tons at 2.5 ppm = 2.5 tons, or 5000 lbs.

MSW landfills. The MSW landfills are currently designed with liners and leachate collection systems to hydraulically isolate the landfill from the groundwater. Some MSW landfills are constructed with double liners for leak detention and redundancy in the groundwater protection systems. Others are constructed with composite liners (including both clay and geomembrances) or double composite liners depending on their hydrogeologic location. Most of these landfills discharge the leachate to publicly owned treatment works (POTWs).

### **Chemical Species**

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as  $\text{HgCl}_2$ , and species bound to particulates are present. Particulate controls on MSW incinerators remove most particulates.

### **Reduction Options and Associated Costs and Impediments**

Any measures to reduce the mercury content of products will eventually result in a decrease in the mercury content of wastes, which will in turn reduce emissions from MSW incineration. There is a time lag, however, because the useful life of many products is several years or more. See the options discussed in the separate section on mercury-containing products in general use.

In the meantime, New Jersey will continue to incinerate at least 25 percent of MSW disposed in the state, and emissions will continue, probably in the range of 300 lbs. per year or more, based on New Jersey's incineration capacity.

Source separation is one option for reducing air emissions of mercury from MSW incinerators. Further steps could be taken to remove mercury-containing items, such as fluorescent tubes, thermostats, and batteries from waste. A municipality, county or the state could ban certain mercury-containing products from disposal or determine them to be a mandatory recyclable material. Alternatively, waste containing mercury could be directed to a landfill rather than to MSW incinerators.

Unfortunately, due to recent court decisions related to State-mandated waste flow, New Jersey no longer has the degree of authority it once had over the flow of solid waste within its borders. A significant volume of solid waste destined for MSW incinerators is received from out-of-district and out-of state sources. Given the economics of disposal, the importation of out-of-district waste may increase.

Without effective waste flow control, a requirement that mercury-containing products should not be incinerated and should only be landfilled will be difficult to implement because New Jersey cannot require communities outside of the State to implement source separation practices. Further, even when the waste flow can be controlled sufficiently, the cost of operating an effective source separation program is high<sup>223</sup>, although perhaps not as high as mercury

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<sup>223</sup> For example, the average cost including transportation to operate a household and small business hazardous waste source separation program appears to be approximately \$0.25/pound. The average cost to operate a pilot curbside/dropoff demanufacturing program for consumer

emissions controls.

While waste separated from disposal and accumulated for separate management may be classified as hazardous waste, the NJDEP has classified some of these waste streams as Universal Waste in accordance with USEPA hazardous waste regulations. This limited exemption from complete hazardous waste regulations is intended to encourage recycling and, means that separated discarded mercury-containing products such as mercury switches, fluorescent lamps, and thermostats can be managed properly without full hazardous waste manifesting and reporting requirements. See separate section on Fluorescent Lamp for more details on New Jersey's Universal Waste Rule.

Further reductions resulting from improvements in emissions control techniques may also be possible.

### **Research, Development, and Monitoring Options**

Monitoring of the inlet stack gas mercury concentrations at all New Jersey MSW incinerators, and monitoring of the total mercury concentration in the ash at two MSW incinerators (Warren County and Essex County) should continue. The data resulting from these monitoring efforts can be used to estimate the concentration of metals in MSW to determine if levels are declining, as expected due to minimization efforts and disposal trends. Current testing protocols should be fully assessed to determine if they are comprehensive.

### **Outreach and Educational Options**

Educating the consumer on the importance of the proper post-consumer-use management of mercury-containing products is recommended. This may be done as previously mentioned through product information. However, the Department may want to consider informing and educating consumers by the use of general awareness publications and/or via the Department's web page.

### **Recommendations**

- Consider revising the State's air pollution control regulation governing Municipal Solid Waste Incinerator (MSWI) emissions to include U.S. EPA's higher efficiency requirement for post-combustion emissions controls, thereby changing New Jersey's alternative limit based on efficiency from 80% to 85%. The 28µg/dscm primary requirement would remain the same.
- Support legislation that will reduce mercury in products sold and used in New Jersey when mercury-free substitutes are available.

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electronics in Union County including transportation is \$0.17/pound. Disposal costs are approximately \$0.025 to 0.050/pound for the tip fee at the facility and \$0.025/pound for collection, handling and transportation costs. The cost to handle special waste separately from the disposal stream is approximately an order of magnitude higher than disposal.

- Require source separation for MSW destined for MSW incinerators.
- Use government purchasing contracts to encourage manufacturers to produce and market low-mercury products.
- Support and fund pilot mercury source separation projects.
- Educate the public about the importance of disposing mercury-containing products and household stockpiles of mercury through household hazardous waste collection.

## Municipal Solid Waste Deposited in Landfills

### Identification and Description of Source

Mercury is present in the solid waste that is disposed of in sanitary landfills. Much of this mercury was intentionally added to products during their manufacture.

### Quantity and Estimated Uncertainty

It has been projected that the total yearly discards of mercury in the U.S. municipal solid waste (MSW) stream in the year 1995 would be about 245 tons, declining to about 173 tons by the year 2000.<sup>224</sup> About 160 million tons of MSW are generated yearly.<sup>225</sup> Assuming that the waste generation quantity has stayed relatively constant during the period, the MSW mercury content would have been about 1.5 ppm in 1995, and about 1.1 ppm by 2000.

Estimates based on New Jersey-specific data are comparable, but suggest a somewhat higher concentration, in the range of  $2 \pm 0.5$  ppm.<sup>226</sup> In 1997, New Jersey generated 16.9 million tons of MSW. Of that amount, 10.3 million tons were recycled and 6.6 million tons were disposed. Of the disposed amount, 2.6 million tons were sent to in-state landfills, 1.6 million tons were incinerated, and 2.4 million tons were disposed out-of-state.<sup>227</sup> Another 0.7 million tons of waste was imported and incinerated. Approximately 65% of the ash from incineration is disposed out-of-state,<sup>228</sup> so, overall, perhaps the mercury represented by 3.4 million tons of MSW is disposed in New Jersey landfills. At two ppm, this translates to about 13.6 thousand pounds of mercury. Another 3.9 million tons of waste (and ash of this waste) representing another approximately 15.6 thousand pounds of mercury, is disposed of out-of-state per year. The uncertainty in the mercury concentration of the waste of perhaps plus or minus 0.5 ppm suggests that the total mercury sent to disposal sites both in-state and out-of-state could range from 22 to 35 thousand pounds, with a mid-point estimate of 29 thousand pounds.

### Sectors Affected

Waste disposal contractors and waste management and disposal facilities could be affected by any measures targeting this sector.

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<sup>224</sup> USEPA, 1992, *Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000*, EPA530-%-92-013, USEPA, Solid Waste and Emergency Response, Washington, D.C.

<sup>225</sup> Office of Technology Assessment, U.S. Congress, 1989, *Facing America's Trash: What Next for Municipal Solid Waste*, OTA-O-424, p., 3, U.S. Government Printing Office, Washington, D.C.

<sup>226</sup> There are two sources of data useful for determining the mercury content of MSW in New Jersey. One source is information on the mercury content of MSW combustion ash; the other is the mercury content of the inlet gas stream at MSW combustion facilities. There is some inconsistency among these data and the resulting calculated mercury content of MSW. The inconsistency may be the result of incomplete volatilization of some mercury-containing items in the MSW waste stream, or variations among the sampling and testing procedures. Overall, a mercury content in the range of 1.5 to 2.5 ppm appears likely.

<sup>227</sup> NJDEP, Division of Solid and Hazardous Waste, January, 2000.

<sup>228</sup> NJDEP, Division of Solid and Hazardous Waste, June, 2000.

## **Receiving Media**

Only a tiny fraction of the mercury deposited in landfills appears to be released in landfill gas and leachate flows. The primary receiving medium is the land surface that constitutes the disposal sites. Sites receiving waste today are engineered and managed to effectively sequester waste and minimize the movement of any of the waste's degradation products to the environment (e.g., leachate capture and treatment). Existing stack test and leachate data (see separate write-ups on landfill air and leachate emissions) indicate that, for mercury, sequestration at disposal sites is efficient.

## **Chemical Species**

Species of mercury in waste can be expected to include all forms in which mercury is found in products, including elemental and divalent. Based on the relatively low emission of mercury from landfills, it is possible that mercury is converted to insoluble, relatively non-volatile forms, such as mercury sulfide,  $\text{HgS}$ , in the landfill environment. In landfills, the typical presence of anaerobic conditions and hydrogen sulfide,  $\text{H}_2\text{S}$ , could encourage such conversion.

## **Reduction Options and Associated Costs and Impediments**

Any measures to reduce the mercury content of products will eventually result in a decrease in the mercury content of wastes. There is a time lag, however, because the useful life of many products is several years or more.

## **Research, Development, and Monitoring Options**

Over the long term, the mercury content of solid waste may be a useful indicator of the decline of mercury use in products. The mercury content of MSW can be approximately estimated by stack tests of influent gas at MSW incinerators and analyses of the mercury content of MSW ash. These analyses, currently performed pursuant to NJDEP permits, should continue.

## **Outreach and Educational Options**

None appear necessary, other than the general recommendation to communicate the importance of reducing or eliminating the mercury content of products.

## **Recommendations**

- Reduce mercury deposited in landfills as addressed in the Mercury in Products recommendations.
- Continue to manage and monitor landfills and upgrade controls on releases from both operating and closed facilities.
- Educate the public about the importance of disposing of mercury-containing products and household stockpiles of mercury through household hazardous waste collection.

## **Sludge Management: Incineration, Land Application, and Disposal**

### **Identification and Description of Source**

Sludge is produced as a byproduct of the treatment of wastewater by sewage treatment plants. Most of the larger plants in New Jersey are publicly-owned, and are termed publicly-owned treatment works (POTWs). Mercury bioaccumulates in the sludge, which is the semi-solid residual byproduct of the wastewater treatment process. Typically, sludge is a combination of organic and inorganic materials and spent micro-organisms used in the treatment process, and can be expected to contain most of the bioaccumulative pollutants entering a POTW. The standard measure of sludge is in dry pounds or dry tons, and represents only the solids content of the residual remaining after treatment of wastewater. Without some form of processing, raw sludge consists of between 92% and 99% liquid.

This sludge typically contains mercury in the parts per million (mg/kg) range. POTWs are a passive recipient of mercury from outside residential, commercial, and industrial source activities. Under existing authority, POTWs can help reduce influent mercury by limiting concentrations in incoming wastewater streams through the establishment of technically-based local pretreatment limits, which they can impose if they themselves are in violation of some standard.

### **Quantity and Estimated Uncertainty**

In 1997, about 200 lbs. of mercury were emitted to the air from the incineration of sludge based on the mercury concentration of incinerated sludge and quantities incinerated. This quantity assumes that at that time 10 New Jersey POTWs incinerated sludge, and that they all emit at a rate proportional to a subgroup of 8 POTWs that are reported to emit approximately 160 pounds of mercury through incineration.<sup>229</sup> About 270 pounds of mercury is in the sludge that is land applied in NJ.<sup>230</sup> It is estimated that about 28% of New Jersey's sludge is shipped out of state for land application, and 6% is shipped out of state for disposal.<sup>231</sup> It can be assumed that exported sludge slated for land application has a mercury content similar to that used in-state in the same manner. This suggests a mercury content of approximately 200 pounds in this sludge. Sludge slated for out of state disposal probably contains a similar concentration of mercury.<sup>232</sup> The estimated 6% of sludge disposed out of state thus could be expected to contain 50 to 100 pounds of mercury.

The total of the subgroups listed above is approximately 750 pounds, as shown in Table 1.

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<sup>229</sup>. Letter from Bob Dixon, Executive Director, Gloucester County Utilities Authority, April 14, 1998.

<sup>230</sup>. NJDEP Bureau of Pretreatment and Residuals, 7/26/99.

<sup>231</sup>. NJDEP Bureau of Pretreatment and Residuals (BPR), personal communication, 7/99.

<sup>232</sup>. Standards POTWs must meet for a variety of parameters are believed to result in consistent concentrations of mercury in sludge, regardless of its disposal category.

Table 1.

## Mercury in NJ Sludge; Estimate Quantities, by Management Method

<b>Management method</b>	<b>Yearly mercury quantity (pounds)</b>
Incineration	200
Land-applied in NJ	270 (includes some sludge generated out-of-state)
Land-applied out-of-state	200
Disposed out-of-state	75
Total	745

A higher quantity of mercury, approximately 1280 pounds, is estimated by multiplying the estimated weighted average<sup>233</sup> mercury concentration of New Jersey sludge (2.3 ppm) by the total quantity of sludge generated (278,900 dry tons in 1997<sup>234</sup>). This 1280 pound value is probably an overestimate, since the weighted average calculation includes values that were below the detection limit but were assumed to be present at a concentration equal to the detection limit. The total quantity of sludge produced may also represent some double-counting because all treatment plants test their sludge for mercury and report the concentration values and quantities, but most plants then send their sludge to another plant for final processing. The second plant again tests for mercury and reports the quantities and concentrations. These several sources of uncertainty are more likely to lead to an overestimation of the total mercury quantity than an underestimation. Therefore, a reasonable estimate is that the total quantity of mercury in New Jersey sludge is about 750 pounds, and is not likely more than about 1000 pounds.

### Sectors Affected

Wastewater treatment plants, most of which are publicly owned, would potentially be affected by programs that sought to limit the amount of mercury passing through and subsequently released, either in sludge, wastewater outflow, or air emissions. Many of New Jersey's treatment plants report concentrations of mercury in their sludge at or near the detection limit. However, several treatment plants, including several that incinerate sludge, have reported mercury concentrations at 5 ppm or higher. Based on the calculations discussed above used to develop a weighted average of New Jersey sludge mercury concentration, some treatment plants appear to contribute a disproportionate share of the overall sludge mercury burden. This may be because these plants accept influent from sources with relatively high mercury discharges. Conceivably, it could be that some plants also process wastewater that is contaminated with mercury that is actually

<sup>233</sup>. Developed by weighting the mean sludge mercury concentration for each reporting treatment plant, based on 1997 mercury concentration data. The plant's reported flow; based on 1999 flow data, was used as the weighting factor. Data was provided by the NJDEP Bureau of Pretreatment and Residuals.

<sup>234</sup>. NJDEP Bureau of Pretreatment and Residuals.



present in the source (potable) water in that service area. However, it is unlikely that source water could supply more than 130 pounds of the approximately 1000 pounds per year of mercury estimated to be present in wastewater treatment sludge.<sup>235</sup>

### Receiving Media

Management of sludge containing mercury has the potential to impact more than one medium. Below is an attempt to define primary and secondary environmental media that are/could be impacted by management method.

<u>Management Method</u>	<u>Primary Medium</u>	<u>Secondary Medium</u>
Land Application	Land	Surface/Ground Water/Air
Composting	Land	Surface/Ground Water/Air
Conversion To Usable Product	Land	Surface/Ground Water/Air
Incineration	Air	Land/Surface Water
Landfilling	Land	Surface/Ground Water/Air

### Chemical Species

Mercury concentrations reported in sludge represent total mercury. It is likely that much of the mercury present in wastewater discharges is present in the divalent ( $\text{Hg}^{++}$ ) form, since other forms are not as soluble. There could be some mercury that is associated with suspended solids in the effluent. In one study, methyl mercury was found in effluent water. (See separate write-up on wastewater discharges.) Mercury species in air emissions from incinerated sludge may be similar to those from other combustion sources. Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as  $\text{HgCl}_2$ , and species bound to particulates are present. There have been suggestions that wastewater treatment plants may have gaseous emissions that contain mercury, both elemental and methyl mercury. The peer-reviewed literature indicates that methyl mercury can be produced in sewage treatment plants, and also that various forms of mercury are released to the atmosphere. Soldano et al. found high levels of atmospheric mercury (both organic and elemental) near sewage treatment plants.<sup>236</sup> Goldstone et al. found that under some conditions,

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<sup>235</sup>. As reported by Eileen Murphy, of the NJDEP Division of Science, Research, and Technology, a study of background mercury concentrations in both ground and surface waters in New Jersey indicates that 40 ng/l (ppb) is the maximum mercury concentration likely to be encountered in these waters. Drinking water purveyors in NJ must report mercury concentrations, and several have at times reported mercury concentrations above the 2 µg/l limit. However, the problem associated with interpreting sample results that are typically at or below the detection limit argues that the 40 ng/l value should be considered a reasonable upper-bound estimate. Multiplying this value by the 1054 million gallons per day wastewater flow as reported by the NJDEP Bureau of Pretreatment and Residuals indicates a maximum mercury inflow to wastewater treatment plants in source water of approximately 130 pounds per year.

<sup>236</sup>. Soldano, B. A., Bien, P. and Kwan, P., Air-Borne Organo-Mercury and Elemental Mercury Emissions with Emphasis on Central Sewage Facilities, *Atmospheric Environment* 9:941-944, 1975.

methyl mercury is produced during the sewage treatment process.<sup>237</sup> *Gilmour and Bloom* studied a municipal sewage treatment plant in which elemental mercury was used as a seal in three trickling filter center columns. They found that the columns were net sources of mercury, and they found significant de novo production of methyl mercury.<sup>238</sup>

### **Reduction Options**

The median mercury concentration in sludge has dropped nearly 50% over the past 15 years.<sup>239</sup> Although data are not readily available to pinpoint all reasons for this decline, the following actions have apparently played a significant role:

- The Industrial Pretreatment Program has reduced the amount of mercury and other pollutants allowed to be discharged from permitted industries to POTWs.
- The Pollution Prevention Program has provided industries with incentives to reduce the amounts of regulated waste produced through process changes and/or substitution to non-regulated raw materials.
- Mercury has been removed from household products (e.g., latex paint) that often found their way into POTW collection/treatment systems.
- More stringent clean up and spill reporting procedures for mercury spills/breakage for sources ranging from schools to research facilities have been implemented.
- Other products and/or technologies have gradually been substituted for historically mercury-based products, e.g., electronic thermometers, blood pressure measuring instruments, etc.

#### *Reduction Options: Source Reduction and Pollution Prevention*

- Phase out use of mercury-containing amalgam for dental fillings coupled with drain traps until phase out is complete.
- Develop a public education program among identified cultural/ethnic groups to reduce use of mercury in ceremonial and/or cultural practices.
- Increase public awareness programs to all medical practitioners, medical institutions, research facilities, educational facilities/institutions and testing laboratories, stressing the proper clean-up of breakage and spills as well as proper handling methods.

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<sup>237</sup>. Goldstone, M. E., et al., The Behaviour of Heavy Metals During Waste Water Treatment: Mercury and Arsenic, *Sci. Tot. Envir.* 95:271-294, 1990.

<sup>238</sup>. Gilmour, C. C. and Bloom, N. S., A Case Study of Mercury and Methylmercury Dynamics in a Hg-Contaminated Municipal Waste Water Treatment Plant. *Water, Soil and Air Pollution* 80:799-803, 1995.

<sup>239</sup>. Based on historical data provided by NJDEP Bureau of Pretreatment and Residuals, 1999.

- Phase out use of mercury in other products that could find their way into wastewater.
- Develop a central clearinghouse to keep abreast of national and international developments that chronicle the elimination, substitution, or reduction of mercury in products or processes. Provide this information to appropriate in-state end users.

#### *Reduction Options: Control and Treatment of Emissions*

Nationally, there is a downward trend in the use of mercury in products, with many uses having been discontinued over the last two decades. It is believed that this trend will continue. Source reduction options such as those discussed above should ensure the continuation of the downward trend in the use of mercury in products, which should translate to a declining concentration of mercury in sludge. For these reasons, it is believed that the reduction options below can be achieved with a minimum of difficulty. The purpose of the reduction options is not to force the shut-down of non-compliant facilities, but to guide facilities to reduce mercury concentrations to levels that are technologically feasible and that are consistent with levels other similar facilities have achieved.

- A concentration limit of 5 ppm, measured with a 12-month rolling average, can be applied to all sludge generated in New Jersey, by a date five years from the present, with a goal of 2 ppm, measured with a 12-month rolling average, within ten years. Limits on mercury discharges to treatment plants, perhaps with extensions of already successful pre-treatment programs to commercial and other facilities with significant mercury concentrations in their wastewater, could be expected to facilitate reductions in sludge concentrations sufficient to meet these levels.
- If, by a date five years from the present, sludge generated by a POTW is not below 2 ppm, measured with a 12-month rolling average, that POTW should evaluate and implement further pre-treatment measures and report on the results annually to the Department. Provision of additional legal authorities to POTWs, if necessary to implement the additional pre-treatment measures, should be considered.
- After ten years, should any facility incinerate wastewater treatment sludge for which the 12-month rolling average mercury concentration exceeds the 2 ppm threshold, a 100 µg/dscm standard for stack emissions, as recommended by the New England Governors' Association, may apply as an alternative standard.
- Additional legal authority should be provided to POTWs if needed to implement the mercury reduction strategies suggested above.
- Cost will be considered as a factor in determining the need for additional control equipment. The effectiveness of controlling mercury emissions from different source types of mercury emissions will be compared and considered.

### *Reduction Options: Research, Development, and Monitoring:*

- Review new or revised risk assessment data for mercury exposure by pathway, and revise, if appropriate, standards for mercury content of wastewater treatment plant sludge by management method based on pathway of concern.
- Obtain a better understanding of the fate and transport of mercury in the land application of sludge.
- Obtain a better understanding of the species of mercury present in the various types of discharges, including sludge, sludge incinerator emissions, wastewater discharges, and air emissions from wastewater treatment plants.

### *Reduction Options: Costs, Difficulties, and Impediments*

The suggested source reduction and pollution prevention opportunities for reducing the amount of mercury reaching POTWs collection and treatment facilities are not estimated to be overly expensive on an annual basis. Most efforts will have to be sustained over extended periods of time to be effective, however.

Depending on the control strategy adopted, the costs involved with end-of-pipe controls could be substantial, and would fall entirely on POTWs.

The costs of obtaining data on the species of mercury in the various media could be substantial. Speciation data could validate the existing assumptions used for sludge mercury standards development or could assist in determining the necessity for revision of the current standards for mercury in sludge.

### **Recommendations**

- Increase public awareness programs regarding the use of mercury in products that find their way into wastewater.
- Identify and phase out the use of mercury in other products that could find their way into wastewater.
- Reduce the use of mercury-containing amalgam through a public education and awareness program, and phase out the use of mercury-containing amalgam for dental fillings.
- Control mercury discharges from dental offices through the use of drain traps.
- Develop an effective public education program to reduce the use of mercury in cultural practices.
- Develop a central clearinghouse to keep abreast of national and international developments; provide this information to appropriate in-state end users.
- A concentration limit of 5ppm, measured with a 12-month rolling average, can be applied to all sludge generated in New Jersey, by a date five years from the present.
- After 5 years, implement a goal of a concentration limit of 2ppm measured with a 12-month rolling average on all sludge generated in New Jersey.

- After 10 years, if sludge exceeds 2 ppm from a facility, measured with a 12-month rolling average, apply an alternate standard of 100F g/dscm for stack emissions.
- Provide POTW's with additional legal authority to implement mercury reduction strategies.
- Review risk assessment data for mercury exposure by pathway and revise mercury content standard for wastewater treatment plant sludge, as appropriate.
- Study the fate and transport of mercury in land application of sludge to develop a better understanding.
- Obtain a better understanding of the species of mercury present in the various types of discharges from wastewater treatment plants.

## **Soils, Contaminated: Thermal Treatment**

### **Identification and Description of Source**

The cleanup of oil-contaminated soil sometimes is done in a device which involves the heating of the soil to drive off the organic matter. This can be done in the temperature range of 400° F (low temperature thermal desorption) to 2000° F (incineration). In either case most, or all, the mercury is driven off, as well as the organic matter.

There are four low temperature thermal desorption (LTTD) units permitted to operate in New Jersey, including 3 commercial units and one dedicated on-site soil cleanup unit. (Others that have operated in the past ten years for site cleanups, but which are not currently operating include the Bog Creek Superfund site, Ocean County, BROS Superfund site, Logan Township, Ryan Murphy LTTD Mercer County for the New Jersey Turnpike petroleum contaminated soils, and the Lipari Superfund Site.)

### **Quantity and Estimated Uncertainty**

Stack testing has been done on 3 of the 4 units. Emissions ranged from 2 to 240 pounds per year per unit if operated at maximum permitted soil throughput and the most recent stack test data is used. Initial tests, conducted 9/98, at one unit (Merck) equated to 138 pounds per year, but improvements in the carbon injection control system reduced annual emissions to about 2 pounds per year (6/99 tests). For this reason, the total emission potential from these 4 units is estimated at approximately 80 pounds per year. However, one unit was not tested for mercury and the others have few tests, so this is an uncertain estimate. LTTD units used for short term (less than 1 year) are not included in the estimate. Also, one of the units (Casie) is working to reduce mercury emissions by testing carbon injection under an Administrative Consent Order. If as successful as the Merck Rahway site, which only treats contaminated soils found on-site, the emissions from this unit should drop to under 5 lbs. per year. Therefore, the annual emission estimate for this source category would be less than 50 pounds per year.

### **Sectors Affected**

Three commercial and one on site cleanup unit for soil currently operate in NJ. Other units could also be permitted.

### **Receiving Media**

The chief receiving medium is air, unless carbon is used, in which case captured mercury on the carbon is usually disposed of in a landfill. See the separate source write ups “Landfill Gas” and “Landfill Leachate” elsewhere in this document.

### **Chemical Species**

Limited estimates of the species of mercury emitted from combustion sources suggest that elemental mercury, oxidized gaseous species, such as  $\text{HgCl}_2$ , and species bound to particles are

present. Since the units described herein operate at lower temperatures, it is expected that oxidized species and species bound to particles would be found in lower quantities, and that elemental mercury could be the dominant species.

### **Reduction Options and Associated Costs and Impediments**

Determine important control device operating parameters and set requirements to minimize mercury emissions, consistent with the significant reductions (about 98%) achieved for the Merck unit.

Require carbon injection, or equivalent control, for units emitting significant mercury emissions (i.e. over 10 pounds per year). Consider setting a uniform mercury emission standard for LTTD units.

### **Research, Development, and Monitoring Options**

Test the one unit (Earle Environmental) which has not been tested for mercury emissions.

Require periodic testing of all LTTD units.

### **Outreach and Educational Options**

None are suggested.

### **Recommendations**

- Determine important operating control parameters and set operating parameter requirements to minimize mercury emissions.
- Require carbon injection or equivalent control.
- Consider settling a uniform mercury emission standard for thermal treatment units.
- Test the one remaining unit that has not been tested for mercury emissions.
- Require periodic testing of thermal treatment units.

## Wastewater

### Identification and Description of Source

Wastewater is generated by households, institutions, commercial facilities, and industrial operations. In New Jersey, most wastewater is discharged to sewage treatment facilities, although some is discharged directly to ground water and surface water. These discharges contain some mercury, although the concentrations are typically at or near the detection limit.

### Quantity and Estimated Uncertainty

All facilities with permitted discharges of mercury to surface and groundwater report their discharges to NJDEP. Many of these facilities are wastewater treatment plants. Mercury loadings to both surface and ground waters, as calculated by NJDEP based on total flows and discharge monitoring reports (DMRs) submitted for 1998, were approximately 820 pounds.<sup>240</sup> About 15% of the New Jersey population is unsewered.<sup>241</sup> Some of the unsewered discharges are included in the DMRs submitted to the NJDEP, but most are not. With the assumption that 15% of the total mercury discharge in wastewater is unaccounted for in the DMR data, the total mercury entrained in wastewater discharges in New Jersey is about 965 pounds.

There is uncertainty with this calculated number, because it is based on an interpretation of DMR values that are, in many cases, at or near the detection limit. The procedure of the NJDEP Bureau of Permit Management is to treat values reported as below the detection limit as being one half of the detection limit. If the detection limit value is high relative to the actual values in the wastewater being tested, the calculated mercury quantity could be an overestimate. If the detection limit value is low relative to the actual values, however, the calculated quantity could be an underestimate. The USEPA is reportedly developing a new analytical method for clean wastewater, method #1631, which will result in lower detection limits. If widely used by POTWs, use of this method offers the possibility of leading to a more accurate, and perhaps lower, estimate of the quantity of mercury in wastewater.<sup>242</sup>

The sources of mercury in wastewater are not well understood. A study carried out in Palo Alto, California suggest that much of the mercury loading comes from consumer products that are discarded in the domestic wastewater stream, as is shown in Table 1.<sup>243</sup> This study found the discharge from dentists' offices to be significantly higher in mercury concentration than other sources, although their flow was relatively low and so this source contributed less than 10% of the total loading. Other studies have suggested that dentists' offices probably contribute about 10% of the mercury loading,<sup>244</sup> and less than 25 percent of the total wastewater load.<sup>245</sup> The Palo

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<sup>240</sup> Bureau of Permit Management, NJDEP, 4/20/99.

<sup>241</sup> Van der Leeden, Frits, Fred Troise, and David K. Todd, 1990, *The Water Encyclopedia*, 2<sup>nd</sup> Edition, Lewis Publishers, Chelsea, MI, 48118, p. 543.

<sup>242</sup> Touminen, Tim, Western Lake Superior Sanitary District, personal communication, March 20, 2000.

<sup>243</sup> Palo Alto Regional Water Quality Control Plant, 1997, *Mercury Source Identification*, Palo Alto Regional Water Quality Control Plant, Palo Alto, CA 94303.

<sup>244</sup> Massachusetts Water Resources Authority, 1997, *Mercury in Dental Facilities*, Massachusetts Water Resources Authority, Sewerage Division, Toxic Reduction and Control Department, September, 1997.



Alto study also found that over 20% of the mercury loading came from the source water. In New Jersey, a study of background mercury concentrations in both ground and surface waters<sup>246</sup> found that 40 ng/l (ppb) is the maximum mercury concentration likely to be encountered in these waters. Drinking water purveyors in NJ must report mercury concentrations, and several have at times reported mercury concentrations above the 2 µg/l limit. However, the problem associated with interpreting sample results that are typically at or below the detection limit argues that the 40 ng/l value should be considered a reasonable upper-bound estimate. Multiplying this value by the NJ wastewater flow going to treatment plants of 1054 million gallons per day<sup>247</sup> indicates a maximum mercury inflow to wastewater treatment plants in source water of approximately 130 pounds per year, nearly 15% of the total loading.

A recent report<sup>248</sup> suggests that source water may contribute a smaller percentage of the total mercury loading to publicly owned (wastewater) treatment works (POTWs). This report found that, in Palo Alto, source water averaged 0.9 ng/l mercury, and in the Great Lakes region source water mercury concentrations ranged between 2 and 4 ng/l. The report concluded that the relative contribution from drinking water to total wastewater mercury content appears to be small (2 to 4%).

This same report discusses a study of influent wastewater at four POTWs around the U.S. This study found that the mean mercury concentration of domestic wastewater, including all values measured, was 178 ng/l. When suspected outliers were excluded, the concentration was estimated to be 138 ng/l. This study estimated that about 10% of the mercury in domestic wastewater came from fish and shellfish consumed. Much of the remaining mercury appeared to come from loss of mercury from dental amalgams resulting from normal wear. One conclusion of this study is that a background mercury concentration averaging more than 100 ng/l can be expected in POTW wastewater influents, even if complete elimination of industrial point source discharges is accomplished. Another conclusion of the report is that loss of mercury from in-place dental amalgams may be the major source of mercury in domestic wastewater.

A background concentration of mercury in wastewater as found in the above-referenced study (approximately 150 ng/l), when multiplied by the yearly wastewater flow in New Jersey, would contribute a total in the range of 500 pounds per year to the total mercury coming into New Jersey wastewater treatment facilities. As noted above, the estimated total amount of mercury in wastewater in the state is estimated to be in the range of 965 pounds, with about 820 pounds contributed by facilities submitting discharge monitoring reports.

It should be noted that a significant portion of the mercury included in wastewater flowing into treatment plants or into septic tanks is likely to accumulate in the wastewater treatment plant sludge or the semi-solid fractions included in septage, and thus not appear in the effluent. (See

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<sup>245</sup> Johnson, William and Teresa Pichay, 2001, Dentistry, Amalgam, and Pollution Prevention, CDA Journal, 29, 509-517.

<sup>246</sup> Eileen Murphy, NJDEP Division of Science and Research, personal communication, 12/99.

<sup>247</sup> NJDEP Bureau of Pretreatment and Residuals, 12/99.

<sup>248</sup> Association of Metropolitan Sewerage Agencies (AMSA), 2000, *Evaluation of Domestic Sources of Mercury*, AMSA, 1816 Jefferson Place, NW, Washington, DC 20036-2505.

sludge management write-up elsewhere in this document.) Adding the approximately 750 pounds of mercury leaving wastewater treatment facilities in the form of sludge gives a total of about 1500 pounds per year mercury exiting New Jersey wastewater treatment plants. Thus perhaps 1/3 of the total mercury discharge from wastewater treatment facilities may be contributed by domestic wastewater.

**Table 1**  
**Mercury Source Identification**  
**Palo Alto, CA Regional Water Quality Control Plant**

Mercury Sources	Average Hg Concentration, (µg/l)	Estimated Flow (gal/year)	Average Hg Load (lbs./year)
Residents	0.24	$5.4 \times 10^9$	11
Water Supply	0.075	$8.1 \times 10^9$	5.1
Dentists	41	$6.2 \times 10^6$	2.1
Permitted Industries	0.19	$7.0 \times 10^8$	1.3
Storm Water Inflow	0.28	$3.1 \times 10^8$	0.7
Employee-Related Human Waste	NA	NA	0.7
Stanford University	0.17	$4.3 \times 10^8$	0.6
Other Known Sources:			
Septage Haulers	62	$4.5 \times 10^5$	0.2
Commercial Laundries	0.31	$1.1 \times 10^7$	0.03
Portable Toilets	1.4	$2.1 \times 10^5$	0.002
Unknown Sources	NA	NA	1.6
<b>TOTALS</b>	<b>0.30</b>	<b><math>9.3 \times 10^9</math></b>	<b>23</b>

### **Sectors Affected**

All dischargers of wastewater would potentially be affected by any programs designed to reduce the mercury loading in this source including residential, commercial (including institutional), and industrial. Dental offices could be especially affected.

### **Receiving Medium**

The receiving medium is surface and ground water.

### **Chemical Species**

The species of mercury in wastewater is unknown. It is likely that much of the mercury present in wastewater discharges is present in the divalent ( $\text{Hg}^{++}$ ) form, since other forms are not as soluble. There could be some mercury that is associated with any suspended solids in the effluent. Water-soluble environmental mercury species include the divalent mercuric ion,  $\text{Hg}^{++}$ , mercuric chloride,  $\text{HgCl}_2$ , the anionic complexes  $\text{HgX}_3^-$ ,  $\text{HgX}_4^{-2}$ , with  $\text{X} = \text{OH}^-$ ,  $\text{Cl}^-$ , or  $\text{Br}^-$ , and

mixed halide complexes such as  $\text{HgCl}_2\text{Br}^{-249}$  although some of the total could also be methyl mercury,  $\text{CH}_3\text{Hg}^+$ .

### **Reduction Options**

Because wastewater mercury concentrations are typically very low relative to the volumes of wastewater, no control recommendations appear feasible, except perhaps for discharges from dental offices. Even in this case, the concentrations are low enough so that end-of-pipe treatment is not likely to be feasible. Source reductions, including the substitution of new materials for mercury dental amalgam, and also including elimination of mercury in any consumer products that contribute significantly to the domestic wastewater flow, appear to be the best options for reducing the load of mercury in wastewater. See the discussion of pollution prevention and source reductions in the sludge management write-up.

### **Recommendations**

- Control mercury discharges from dental offices.
- Substitute new materials for mercury dental amalgam, and eliminate mercury in any consumer products that contribute significantly to the domestic wastewater flow.

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<sup>249</sup>. DeNoble, James P., 1999, Critical Review: *Atmospheric Methylmercury: Sources, Sinks, and Inferences for its De Novo Generation*, DRAFT Masters Thesis, Rutgers University, October, 1999.

## Naturally Occurring Emissions

### Identification and Description of Source

Mercury is relatively rare in the earth's crust. The dominant natural form of mercury is mercury sulfide, HgS, also known as cinnabar, an extremely insoluble compound. Mercury is emitted in trace quantities from soils and water bodies, including the ocean, in a natural cycle and much of the natural emission may be from volcanoes, with some from erosion and some from the decay of both terrestrial and marine plants.<sup>250</sup> Over the past 100 years, anthropogenic activities have led to the emission of approximately 200,000 tons of mercury.<sup>251</sup> Of this total, about 3000 tons are now in the atmosphere, about 7000 tons are in the surface ocean, and about 190,000 tons have accumulated in surface soils. These quantities have increased the "natural" emission from the surface ocean by a factor of three, although they have not appreciably changed the natural emission from surface soils.<sup>252</sup>

### Quantity and Estimated Uncertainty

The mean natural emission of mercury from land has been estimated to be about 9.7  $\mu\text{g}/\text{m}^2/\text{yr}$ .<sup>253</sup> Although mercury deposits occur in all types of rocks, the geologic environments that typically host mercury deposits are unlike those in the New Jersey coastal plain.<sup>254</sup> There are no known deposits of mercury elsewhere in New Jersey, and no volcanoes. There is no reason to believe that emissions from the land surface in New Jersey are significantly higher than the mean natural flux. With a land area of about 2,000,000 hectares, or  $2 \times 10^{10} \text{ m}^2$ , natural emissions of mercury from New Jersey are estimated at approximately 190 kg, or 420 pounds, per year.

Both wet and dry deposition of mercury to the land surface occur. This input is discussed in Chapter 1 of Volume III. This deposition includes both natural and anthropogenic components. The present atmospheric burden of mercury is estimated to have increased by approximately a factor of three from pre-industrial times.<sup>255</sup> There is ample evidence that global mercury deposition rates have increased significantly over the past 150 years.<sup>256</sup> In one study, mercury accumulation rates in Great Lakes' sediments were found to have increased by factors ranging from 50 to over 200 from pre-industrial to modern

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<sup>250</sup> Nriagu, Jerome O., 1989, A global assessment of natural sources of atmospheric trace metals, *Nature*, 338, 47-49.

<sup>251</sup> Fitzgerald, W., and R. Mason, 1996, The global mercury cycle: oceanic and anthropogenic aspects, in W. Baeyens, et al (eds.), *Global and Regional Mercury Cycles: Sources, Fluxes and Mass Balances*, 85-108, Kluwer Academic Publishers, Netherlands.

<sup>252</sup> Fitzgerald and Mason, 1996.

<sup>253</sup> Fitzgerald and Mason, 1996.

<sup>254</sup> Dooley, John, 1992, Natural sources of mercury in the Kirkwood-Cohansey aquifer system of the New Jersey coastal plain, New Jersey Geological Survey, Trenton, NJ, 08625.

<sup>255</sup> Fitzgerald, W. F., 1995, Is mercury increasing in the atmosphere? The need for an atmospheric mercury network (AMNET), *Water, Air, and Soil Pollution* 80, 245-254.

<sup>256</sup> Fitzgerald, William, Daniel Engstrom, Robert Mason, and Edward Nater, 1997, The Case for atmospheric mercury contamination in remote areas, *Environ. Sci. Technol.*, 32, 1-7.

times.<sup>257</sup> Even in relatively remote areas, mercury accumulation rates appear to be 3 or more times higher now than before the industrial age.<sup>258,259</sup> Atmospheric deposition rates in New Jersey are generally higher than in most of the U.S.,<sup>260</sup> even though New Jersey has no known significant natural sources. It is likely that anthropogenic sources dominate the atmospheric deposition quantity in New Jersey by at least a factor of 2, and perhaps by a factor of 50 or more.

### **Sectors Affected**

No sectors are directly affected.

### **Receiving Media**

The natural emissions discussed herein are to the atmosphere. Data were not found on natural emissions to or from other media. Changes in such emissions may also have resulted from human activity, although, due to the heterogeneity of aqueous and terrestrial environments compared to the atmosphere, detecting the degree of any such changes will likely be more difficult.

### **Chemical Species**

The primary species of natural emissions is believed to be elemental mercury.

### **Reduction Options and Associated Costs and Impediments**

Emissions of naturally-occurring mercury from soils are not likely to be affected by human activities. Reduction of anthropogenic emissions can be expected over time to reduce the current anthropogenic perturbation of the natural mercury cycle. This perturbation, as discussed elsewhere, appears to primarily affect water bodies, including the surface of the ocean.

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<sup>257</sup> Pirrone, N., I. Allegrini, G. Keeler, J. Nriagu, R. Rossmann, and J. Robbins, 1998, Historical atmospheric mercury emissions and depositions in North American compared to mercury accumulations in sedimentary records, *Atmospheric Environment*, 32, 929-940.

<sup>258</sup> Lorey, Peter, and Charles Driscoll, 1999, Historical trends of mercury deposition in Adirondack Lakes, *Environ. Sci. Technol.*, 33, 718-722.

<sup>259</sup> Swain, Edward B., D. Engstrom, M. Brigham, T. Henning, and P. Brezonik, 1992, Increasing rates of atmospheric mercury deposition in mid-continental North America, *Science*, 257, 784-787.

<sup>260</sup> Eisenreich, S. J. and J. Reinfelder, 2001, *Interim Report to the New Jersey Department of Environmental Protection, The New Jersey Atmospheric Deposition Network (NJADN)*, Department of Environmental Sciences, Rutgers University, New Brunswick, NJ 08901.

## **Appendix III-A: Evaluation of Control Options for Three Source Categories**

Data relevant to setting mercury emission limits includes mercury concentration, flue gas flow rate, and annual emissions. Comparisons of these parameters are provided in graph form for three source categories: coal boilers, municipal solid waste (MSW) incinerators, and iron and steel furnaces. Data indicates that coal fired utilities generally emit relatively low concentrations of mercury (ranging from 1 to 20 : g/dscm or 5 to 100 milligrams per megawatt hour (mg/MW hr)) in high flue gas flows, resulting in significant annual emissions. Mercury emissions concentrations for iron and steel industry are in the range 10 to 100 : g/dscm, which is between MSW inlet and outlet emissions, and higher than coal outlets. High gas flow also results in substantial annual mass emissions from iron and steel production. Iron and steel plants have a wide range of gas flows, as low as MSW and as high as coal combustion.

### **Emission Standards for Municipal Solid Waste incinerators**

In 1994, NJ adopted rules to set an interim mercury emission standard of 65 : g/dscm to be met by the year 1996 and 28 : g/dscm to be achieved by the year 2000. 80% reduction was set as an alternative standard in case source separation was unsuccessful. The mercury emissions standard of 28 : g/dscm was set based on a presumption of at least 80% control with carbon injection and 80 % reduction with source separation/waste stream mercury reduction measures. Testing over the last 5 years have demonstrated that carbon injection on MSW incinerators can consistently achieve over 95% mercury reduction with baghouse particulate collection and over 90% mercury reduction with electrostatic precipitator (ESP) particulate control. Inlet mercury concentrations vary widely around a 300 : g/dscm average, which has dropped from an average of 700 : g/dscm in the early 1990's. The mercury control experience with MSW incinerators demonstrated the benefits of a good mercury waste recycling program, the superior performance of baghouse control when compared to ESP's, and increased mercury removal efficiency with increased carbon injection.

Subsequent to New Jersey's mercury emission standard, the federal EPA also adopted mercury limits. The federal 80 : g/dscm or 85% control standard did not consider mercury in waste reduction and incorporated a higher control efficiency alternative limit. Based on the demonstrated success of carbon injection, New Jersey can increase the control efficiency component of the NJ mercury standard to the federal 85% level.

New Jersey currently requires that the most effective air pollution control be used when existing control devices are replaced. Hence, MSW incinerators should replace electrostatic precipitator (ESP) particulate control with more effective baghouses at the end of the useful life of the ESP's. This will cause mercury emissions to decrease from the ESP controlled facilities over the long term.

## **Emission Standard Considerations for Coal Fired Boilers**

Based on limited testing of NJ coal fired boilers, lower emission concentrations of mercury appear to be related to use of baghouse particulate control, wet scrubbing, selective non-catalytic reduction (SNCR), and low sulfur washed coal. Based on pilot testing, a slip stream of flue gas, carbon injection prior to particulate control devices on coal fired boilers can significantly reduce mercury emissions.

It is appropriate to consider a combination of limits for a mercury emission standard. An electrical output based component expressed as mg/MWhr limit would promote higher energy efficiency. A percent reduction component would address the wide range of uncontrolled emissions, similar to MSW. The variability of mercury concentrations from coal fired boilers appears to be the result of the variability of mercury in coal and the varying ability of the existing control systems to remove mercury. The percent reduction alternative would act as a safety value for high mercury coals and allow a reasonably low mg/MWhr primary limit (applicable to average coal) to achieve significant overall reductions. Hence, a logical format for a standard would be "X mg/MWhr or Y % reduction, whichever results in the higher emission level".

A reasonable percentage reduction of emissions with mercury control systems would likely be in the range of 75 to 90%. For large MSW incinerators, EPA incorporated 85% reduction in its mercury standards. Stack testing has demonstrated that 95% and 98% reduction can be achieved by carbon injection on MSW incinerators operating with ESPs and baghouses respectively. Since mercury from coal combustion is at lower concentration and more likely to be elemental, lower removal efficiencies are expected.

Most of the coal fired units in NJ are emitting 10 to 20 mg/MWhr of mercury. Assuming 75 % reduction, mercury emissions would be lowered to the range of "2.5 to 5 mg/MWhr". Assuming 90 % reduction, mercury emissions would be in the range of "1 to 2 mg/MWhr". Based on evaluation of these limited NJ data, an appropriate standard would likely be in the range of "1 to 5 mg/MWhr or 75 to 90% reduction". Similar to MSW regulation, the Department could adopt rules that phase in limits over time. Given the federal requirement to propose a national mercury limit by December 2003, the substantial mercury in coal and emission data being evaluated by the USEPA, and national efforts to further evaluate mercury control; it is premature for the NJ Mercury Task Force to propose a specific mercury limit at this time.

## **Emission Standard Considerations for the Iron and Steel Industry**

Mercury emissions concentrations for iron and steel production are in the range 10 to 100 : g/dscm, which is between MSW inlet and outlet mercury concentrations, but higher than coal outlet mercury concentrations. Consequently, if it is feasible to reduce mercury emissions from MSW and coal, it should be feasible to reduce mercury emissions from iron and steel. Separation of mercury containing waste materials from MSW and reduction of mercury use in products resulted in reducing average mercury emissions by

about 60%. Similarly, scrap management could significantly lower iron and steel mercury emissions, perhaps by greater amounts.

Existing air pollution control systems on iron and steel furnaces may control mercury, but the Department does not have any mercury emission data on emissions from iron and steel plants before existing particulate control. Iron and steel furnaces with baghouses could use carbon injection to significantly reduce mercury emissions, as was done with the MSW incinerators. With respect to facilities with scrubbers, the NESCAUM report dated September 2000, page IV-7, indicates some scrubbers have been observed to remove 85-95% of oxidized mercury. However, the species of mercury from iron and steel production may be primarily elemental, which is harder to catch with carbon and scrubbing. Measures to oxidize mercury may be useful to increase removal efficiency of control.

A standard in the form of percent reduction of stack outlet is inappropriate because it does not give credit for mercury reductions from existing control and would not give credit for mercury reductions from scrap management. Percent reduction for inlets to control may be feasible, but would require 2 simultaneous tests and does not promote energy efficiency or pollution prevention.

An effective concentration limit in : g/dscm or an output based limit in mg/ton of iron and steel may be feasible, but the variability of mercury in scrap would need to be addressed.

A combination of pollution prevention or percent reduction limits (mg/ton or % reduction) may be the most appropriate format for a standard. A production related limit in terms of mg/ton will be better than : g/dscm because it will promote energy efficiency and pollution prevention. The combination standard may be most reasonable for a wide range of uncontrolled emissions. The percent reduction alternative provides a flexible standard for high mercury scrap and allows a reasonably low mg/ton primary limit (applicable to average scrap) to be set in order to achieve significant overall reduction. The percent reduction (of the control system inlet) component may be most appropriate as an interim standard, and could be eliminated in the longer term. The long-term standard could be a uniform mg/ton pollution prevention standard, as mercury is eliminated from products that become scrap iron and steel. Additional mercury emission data is needed to determine the effectiveness of mercury waste separation and air pollution control systems prior to setting a specific mercury standard for iron and steel production.



## Appendix III-B: Calculation of Mercury Releases from Products in Use and During the Waste Disposal Process (Not Including Fluorescent Tubes)

It is assumed that the primary species of mercury subject to volatilization is elemental mercury, which is contained in items including switches and measuring devices. Likewise, the quantity of mercury released from products that break or otherwise spill mercury during their use can also be estimated from assumptions and estimates regarding the quantities involved, and physical data for mercury.

To estimate the release due to volatilization during the waste disposal process, the following procedure was used. First, the total amount of mercury in the solid waste stream was estimated, based on the report that about 8 million tons of solid waste is generated per year<sup>261</sup> and with the assumption that the mercury content of this waste is 2.0 ppm.<sup>262</sup> It is estimated, based on waste composition and use data,<sup>263</sup> that 10% of the mercury in solid waste is contributed by fever thermometers, 6% is contributed by thermostats, and 1% by other items, including light switches. It was further assumed that, during disposal, 90% of the thermometers would break and release contained mercury and that 5% of the other items would break. (An additional amount of the mercury in municipal solid waste is contributed by fluorescent tubes, virtually all of which would break during disposal. See the separate section describing this source. Also, mercury present in switches, etc. in discarded automobiles can contaminate recycled metals; see separate write-ups on aluminum and aluminum scrap processing and iron and steel manufacture.) Based on the solid waste quantity, its mercury concentration, and the above waste content percentages and estimated percentage of breakage, the mercury contained in broken thermometers, thermostats, and other items in the municipal solid waste stream totals about 2900 pounds per year (1300 kg/yr.). It was then assumed that this mercury from broken items would be dispersed during the waste handling process into spheres of various diameters, and the surface area of these spheres was estimated.<sup>264</sup>

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<sup>261</sup> NJDEP, 2000, Division of Solid and Hazardous Waste, Trenton, NJ 08625.

<sup>262</sup> See separate section, "Solid Waste Deposited in Landfills" in this report.

<sup>263</sup> USEPA, 1992, *Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000*, EPA530-R-92-013, USEPA, Washington, D.C.

<sup>264</sup> It is assumed that the 1300 kg of mercury would be liquid that would be dispersed to a greater or lesser degree depending on how small the spheres of mercury are that form during the breaking and mixing from solid waste processing. If the spheres that form are spherical and all 1 mm in radius, each one would have a volume of 4.2 mm<sup>3</sup> and a surface area of 12.6 mm<sup>2</sup> (using the formulae that the volume of a sphere is  $\frac{4}{3}\pi r^3$  and the surface area of a sphere is  $4\pi r^2$ ). If the sphere is 0.1 mm in radius, each would have a volume of 0.0042 mm<sup>3</sup> and a surface area of 0.126 mm<sup>2</sup>. If the spheres are 0.01 mm in radius, each would have a volume of  $4.2 \times 10^{-6}$  mm<sup>3</sup> and a surface area of 0.00126 mm<sup>2</sup>. Mercury's density is 13.546 g/cm<sup>3</sup> at 20 C. 1300 kg of mercury thus would have a volume of 98,000 cm<sup>3</sup>. If this volume was in the form of spheres of 1 mm radius, there would be about 23,000,000 of them, and their surface area would be about 2,900,000 cm<sup>2</sup>. If the volume was in the form of spheres of 0.1 mm radius, there would be

The rate at which mercury with the estimated surface area would volatilize was then estimated, based on a series of calculations.<sup>265</sup> In this rate calculation it was assumed that the disposed items and the mercury entrained with them would be present in the solid waste management system for a period of two weeks. (After this time the mercury would be within a disposal site, such as a landfill or an incinerator, for which emissions are estimated and described in separate reports.) Combining the estimated rate of mercury volatilization and the estimated surface area of the mercury in the waste stream leads to an estimated release in the range of 80 pounds, per year.<sup>266</sup>

A similar procedure can be used to estimate the quantity of mercury released from products that break or otherwise spill mercury during their use. For this procedure, an estimate of the entire stock of mercury-containing items in use must be estimated. Such an estimate can be developed using a procedure based on various assumptions and

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23,000,000,000 of them, with a surface area of 29,000,000 cm<sup>2</sup>. If the volume is in the form of spheres of 0.01 mm radius, there would be 23,000,000,000 of them, with a surface area of 290,000,000 cm<sup>2</sup>.

<sup>265</sup> Dragun, James, 1988, *The Soil Chemistry of Hazardous Materials*, Haz. Mat. Cont. Res. Institute, Silver Spring, MD, presents a formula relating the evaporation rate of a substance to that of water. The formula is:

$$E_m = E_w (v_p M * \sqrt{M W_m}) / (v_p W * \sqrt{M W_w})$$
, where

$E_m$  is the evaporation rate of mercury,

$E_w$  is the evaporation rate of water,

$v_p M$  is the vapor pressure of mercury,

$M W_m$  is the molecular wt. of mercury,

$v_p W$  is the vapor pressure of water, and

$M W_w$  is the molecular wt. of water.

The vapor pressure of Hg at 20° C is reported as 0.001201 mm Hg, and that of water is 17.535 mm Hg. The evaporation rate of water ( $E_w$ ) at 70° F, with a 1 mph wind and 50% relative humidity is reported as 11.04 cm/month. (The reference for this is web site [www2.nishikigoi.or.jp/bbs\\_a/messages/1768.html](http://www2.nishikigoi.or.jp/bbs_a/messages/1768.html), which references a book by E.F. Schulz, *Problems in Applied Hydrology*, Colorado State University, 1976.)

Since a cm<sup>3</sup> of water weighs 1 gram, its evaporation rate in terms of mass per surface area would be 11.04 g/cm<sup>2</sup> per month. Using the formula above,  $E_m$ , the evaporation rate of mercury, at these same conditions, would be 0.0025 g/cm<sup>2</sup> per month, or 0.00125 g/cm<sup>2</sup> per two week period.

<sup>266</sup> The surface area estimate, and the resulting volatilization estimate, is dependent on the assumed size of the spheres of mercury. With the 1 mm radius spheres, with a total surface area of 2,900,000 cm<sup>2</sup>, 3.7 kg Hg would volatilize during a two week period. With the 0.1 mm radius spheres, with a total surface area of 29,000,000 cm<sup>2</sup>, the volatilization would be 37 kg. With the 0.01 mm radius spheres, with a total surface area of 290,000,000 cm<sup>2</sup>, the volatilization would be 370 kg. It is unlikely that elemental mercury would be pulverized much more finely than into spheres of 0.1 mm radius. With spheres this size, 37 kg per year, or 81 pounds per year, of the mercury contained in the waste stream from broken thermometers, thermostats, and other items including switches would volatilize on the way to disposal sites.

national data on quantities of mercury used over the past 50 years in various types of products.<sup>267</sup>

The first step in this procedure was to identify the national quantities of mercury used in applications where elemental mercury could conceivably be released if a product broke or the contained mercury spilled for some other reason. These uses are considered to be laboratory uses, wiring devices and switches, and measuring and control instruments. Releases from laboratory uses are discussed in another section in this document. The mercury used in wiring devices and switches was included in the “electrical, total” category until 1977. In 1978 and into the early 80s, wiring devices and switches represented about 10% of the electrical total, and it is assumed to have represented a similar percentage prior to that. Based on its share of the U.S. population, NJ is assumed to account for 3% of the national use. The estimated New Jersey quantity used for wiring devices and switches and measuring and control instruments is about 15,000 pounds per year up until the early 1980s, and declining from then to a yearly use of about 5,000 pounds by the late 1990s.

With the assumption of a 15-year half-life for this type of product, it can be estimated that the New Jersey inventory of mercury in products of this type is currently about 250,000 pounds.<sup>268</sup> (Approximately 20,000 pounds of mercury is estimated to be present in dental amalgam tooth fillings in the New Jersey population,<sup>269</sup> raising the total broad estimate of the inventory of mercury in New Jersey to nearly 300,000 pounds.)

Each year, some of this mercury in the New Jersey inventory will be removed. Most of this removed mercury, representing products discarded or recycled, will find its way to disposal sites or to recycling facilities, including facilities that recycle scrap metal. (Estimated releases from these types of sites are described separately in this document.)

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<sup>267</sup> U.S. Geological Survey, various years, as described in Mercury Minerals Yearbooks for various years, formerly prepared by the U.S. Bureau of Mines and now prepared by the U.S. Geological Survey, Minerals Information, 983 National Center, Reston, VA 20192.

<sup>268</sup> The approximate 15,000 pound per year use can be assumed to disappear from service in a manner typical of first-order exponential degradation. With a 15-year half-life, half of an original yearly quantity would remain after 15 years, and after a period of time, a steady-state quantity would be expected to develop where the yearly loss equals the yearly input. The relationship in the steady-state situation can be expressed as  $M_i = M \times k$ , where  $M_i$  represents the yearly input mass,  $M$  represents the total mass in the system, and  $k$  represents the loss rate (i.e., portion of the total lost per year). With a 15-year half-life,  $k \approx 0.046$  per year, and with  $M_i = 15,000$  pounds per year,  $M \approx 325,000$  lbs. With use declining in an approximately linear manner to a late 90s level of about 5,000 pounds per year, the current NJ inventory of mercury contained in wiring devices, switches, and measuring and control instruments, estimated numerically, is approximately 250,000 pounds.

<sup>269</sup> This assumes a mean weight of dental filling of 2 grams per person in New Jersey, of which 50% is mercury. This is based on the assumption that the average person has less filling material than the mean weight of filling material of a person at age of death, estimated to be 2.9 g (see write-up on Crematoria, elsewhere in this document). Multiplying 1 g by 8,000,000 (the approximate population of New Jersey) gives a total mercury quantity in in-place amalgam fillings of 8,000 kg, or about 18,000 pounds.

Some of the inventory quantity will be lost directly to the environment, however, due to breakage of items and spillage of the mercury contained.

As with the procedure used to estimate releases during waste handling described above, this spilled mercury can be assumed to form into spheres, with an approximate diameter which may vary from about 0.1 to about 1 mm. The total surface area and subsequent rate of volatilization of the mercury can then be estimated. It is assumed herein, for a first approximation, that 0.5 % of the estimated 250,000 pounds of mercury contained in wiring devices, switches and measuring and control instruments in New Jersey is lost directly due to breakage and spillage each year. This is 1250 pounds. If this mercury is represented by spheres between 1.0 and 0.1 mm in diameter, the same set of calculations used above leads to a yearly emission estimate in the range of 40 to 400 pounds per year.<sup>270</sup>

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<sup>270</sup> The calculation procedures are the same as described in footnotes 4, 5, and 6, above, except that the quantity is 568 kg (1250 lbs.) and the mercury is assumed to volatilize for the entire year instead of a two-week period.

## Appendix III-C: Calculation of Potential Mercury Air Emissions from the Land Disposal of Dredged Materials

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### Assumptions

1. Background information of the dredged materials from NY/NJ Harbor (NJ DEP):
  - a. 6 million cubic yards of dredged material removed from New Jersey waterways each year;
  - b. 75% land disposal of dredged material;
  - c. 40% solid content;
  - d. Total porosity: 54.7 - 56.3 v/v %;
  - e. Sediment moisture content: >4%. (31% of moisture assumed in calculation);
  - f. Exposed area of the storage reservoir (CDF): 30 acres.
2. Total mercury (Hg) concentration in the dredged materials:
  - a. Average concentration of Hg: 2.88 mg/kg (ppm) (NJ DEP);
  - b. Maximum concentration of Hg: 13.6 mg/kg (ppm) (NJDEP);
  - c. Fraction of elemental Hg as total Hg: 3% (Lawson et al., 2000);
  - d. Mercury concentration in the ambient air: 2.6-6.5 ng/m<sup>3</sup> (Eisenreich & Reinfelder, unpublished data).
3. Frequency of replenishment or refill of the dredged materials (NJDEP):
  - a. Every 7 days (Could be disturbed every ~ 3 days.)
4. Expose time of the dredged materials to the air (NJ DEP):
  - a. 7 days (Could be ~ 3 days due to disturbance.)
5. Wind velocity (as shown in Table 1):
  - a. 5 km/hour
  - b. 12 km/hour
  - c. 35 km/hour

### Calculations and Results

1. Amount of dredged material disposed of on land each year:
  - a. 1 cubic yard = 0.765 cubic meter; dry density of dredged material = 2.65 g/cm<sup>3</sup>;
  - b.  $6 \times 10^6$  cubic yard  $\times$  0.765 m<sup>3</sup>/yd<sup>3</sup>  $\times$  75% land disposal  $\times$  40% solid content  $\times$  2.65 ton/m<sup>3</sup> =  $3.65 \times 10^6$  dry tons of dredged material disposed of on land each year
2. Annual loadings of mercury to CDF along with the dredged materials each year:
  - a. Average loadings of Hg =  $3.65 \times 10^6$  tons  $\times$  2.88 ppm = 10.5 tons (or 10,500 kg)
  - b. Maximum loadings of Hg =  $3.65 \times 10^6$  tons  $\times$  13.6 ppm = 49.6 tons (or 49,600 kg)
3. Potential annual average Hg emissions of Hg to the air from 30 acre CDF site:
  - a. Based on 7-day and 3-day cycle periods, provided Hg concentration = 2.88 ppm.

Table III-C.1 Mercury volatilization from 30 acre CDF site (Ave Hg conc. = 2.88 ppm)

Period of a Cycle (day)	Wind Speed (km/h)	Daily Flux ( $\mu$ g/m <sup>2</sup> /day)	Daily Emission (g/day)	Cycle Loading (g/cycle)	Annual Loading (kg/year)	Percentage of Hg Emittted (%)
7	5	5.29	0.64	4.5	0.234	0.0047
7	12	5.82	0.71	4.95	0.258	0.0052
7	35	6.23	0.757	5.3	0.276	0.0055
3	5	7.43	0.901	2.70	0.329	0.0066
3	12	8.44	1.02	3.07	0.374	0.0075
3	35	9.25	1.124	3.37	0.41	0.0082

- b. Based on 7-day and 3-day cycle periods, provided Hg concentration = 13.6 ppm

Table III-C.2. Mercury volatilization from 30 acre CDF site (Max. Hg conc. = 13.6 ppm)

Period of a Cycle (day)	Wind Speed (km/h)	Daily Flux ( $\mu\text{g}/\text{m}^2/\text{day}$ )	Daily Emission (g/day)	Cycle Loading (g/cycle)	Annual Loading (kg/year)	Percentage of Hg Emitted (%)
7	5	24.98	3.02	21.20	1.11	0.0047
7	12	27.48	3.35	23.38	1.22	0.0052
7	35	29.42	3.57	25.03	1.30	0.0055
3	5	35.09	4.25	12.77	1.55	0.0066
3	12	39.86	4.84	14.51	1.77	0.0075
3	35	43.70	5.31	15.92	1.94	0.0082

**Comments and Suggestions:**

1. The results are tabulated in Table 1. Although the dredging-spreading-lifting-compacting cycle lasts about 7 days, I also used "3 day cycle" for a reference. Because the dredged materials are frequently "disturbed" after they are put in CDF, a 3-day cycle may give you an apparent reference.
2. I made the wind speed as a variable and assumed three different wind speed conditions: calm, fair and windy, for comparison purpose.
3. As this is theoretical calculation based on the assumptions, the laboratory and field validations may be needed.

## Acronyms

ACE	Army Corps of Engineers
AHA	American Hospital Association
ATSDR	Agency for Toxicology and Disease Registry
B/ISW	Bulk and industrial solid waste
BMP	Best management practices
BTU	British thermal units
CDC	Center for Disease Control
CDF	Confined disposal facilities
CEM	Continuous emissions monitoring
CESQG	Conditionally exempt small quantity generators
CPSC	Consumer Products Safety Commission
CRTK	Community Right-to-Know
DMR	Discharge Monitoring Reports
DNSC	Defense National Stockpile Center
DOE	Department of Energy
DSHW	Division of Solid and Hazardous Waste
ECOS	Environmental Council of States
EDECA	Electric Discount and Energy Competition Act
EEI	Edison Electric Institute
EPA ORD	Environmental Protection Agency Office of Research & Development
EPCRA	Emergency Planning and Community Right to Know Act
ESCO	Energy service contractors
ESP	Electrostatic precipitators
FGD	Flue gas desulphurization
GHG	Greenhouse gas
HARS	Historic Area Remediation Site
Hg	Mercury
Hg <sup>++</sup>	Oxidized ionic mercury
Hg <sup>o</sup>	Elemental mercury
HHW	Household hazardous waste
HID	High intensity discharge
HVAC	Heating, ventilation and air conditioning
LTTD	Low temperature thermal desorption
MCL	Maximum contaminant level
MeHg	Methylmercury
MOU	Memorandum of understanding
MSW	Municipal solid waste
MSWI	Municipal solid waste incinerator
MWC	Municipal waste combustors
MW-Hr	Megawatt hour
MWI	Medical waste incinerator
NACCHO	National Association of City/County Health Officials
NARUC	National Association of Regulatory Utility Commissioners



NASEO	National Association of State Energy Officials
NEGECP	New England Governors and Eastern Canadian Premiers
NEIWPC	Northeast Interstate Water Pollution Commission
NEMA	National Electronic Manufacturers Association
NESCAUM	Northeast States for Coordinated Air Use Management
NEWMOA	Northeast Waste Management Officials Association
NJADM	NJ Air Deposition Network
NJBPU	NJ Board of Public Utilities
NJDOT	NJ Department of Transportation
NJPDES	New Jersey Pollutant Discharge Elimination System
NJSA	NJ Statutes Annotated
NOAA	National Oceanic and Atmospheric Administration
NPO	Nonproduct output
OSHA	Occupational Safety and Health Administration
OTC	Ozone Transport Commission
PBT	Persistent, bioaccumulative, and toxic substance
PJM	Pennsylvania, New Jersey and Maryland
PMA	Phenyl mercuric acetate
POTWS	Publicly owned treatment works
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RHgX	Reactive halogenated mercury
RMW	Regulated medical waste
RPPR	Release and Pollution Prevention Report
RPS	Renewable portfolio standard
SEP	Supplementary environmental project
SIC	Standard Industrial Classification
SRP	Site Remediation Program
STAPPA	State and Territorial Air Pollution Program Administrators
STAPPA/ALAPCO	State and Territorial Air Pollution Program Administrators - Association of Local Air Pollution Control Officials
TARP	Technology Acceptance and Reciprocity Partnership
TCLP	Toxicity Characteristic Leaching Procedure
TRC	Thermostat Recycling Corporation
TRI	Toxic Release Inventory
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UWR	Universal Waste Rule
WQC	Water Quality Certificate